RI051270DF

DRAFT FINAL
FEASIBILITY STUDY

REMEDIAL INVESTIGATION /FEASIBILITY STUDY

INDUSTRI-PLEX SITE
WOBURN, MASSACHUSETTS

RESPONSE ACTION CONTRACT (RAC), REGION I

For
U.S. Environmental Protection Agency

By
Tetra Tech NUS, Inc.

EPA Contract No. 68-W6-0045
EPA Work Assignment No. 116-RICO-0107
TtNUS Project No. GN4123

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Gordon Bullard
Project Manager

for Arnold Ostrofsky
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ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or Relevant and Appropriate Requirements
AVS	acid volatile sulfide
BECO ROW	Boston Edison Company Right of Way
BTEX	benzene, toluene, ethyl benzene, xylene
CBCA	Cranberry Bog Conservation Area
CCC	Criterion Continuous Concentration (chronic)
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	cubic foot
CFR	Code of Federal Regulations
cfs	cubic feet per second
CMC	Criterion Maximum Concentration (acute)
CMR	Code of Massachusetts Regulations
COC	contaminant of concern
COD	chemical oxygen demand
COPC	contaminant of potential concern
Cr	chromium
CT	central tendency
CWA	Clean Water Act
CY	cubic yard
DCA	dichloroethane
DCE	dichloroethene
DDT	p,p'-Dichlorodiphenyltrichloroethane
DO	dissolved oxygen

DOC	dissolved organic carbon
DPT	direct push technology
DS	deep sediments
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
Fe	iron
FS	Feasibility Study
gpd	gallons per day
g/hr	grams per hour
gpm	gallons per minute
GSIP	Groundwater/Surface Water Investigation Plan
GW	groundwater
HBHA	Halls Brook Holding Area
Hg	mercury
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
I-95	Interstate 95
I-93	Interstate 93
ILCR	Incremental Lifetime Cancer Risk
ISRT	Industri-Plex Site Remedial Trust
IWPA	Interim Wellhead Protection Area
lb	pound
LEDPA	Least Environmentally Damaging Practicable Alternative
LF	linear foot
LOAEL	lowest observed adverse effect level

MADEP	Massachusetts Department of Environmental Protection
MBTA	Massachusetts Bay Transportation Authority
MCL	maximum contaminant limit
MCP	Massachusetts Contingency Plan
MDC	Metropolitan District Commission
M&E	Metcalf & Eddy, Inc
mgd	million gallons per day
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MIT	Massachusetts Institute of Technology
MOA	Memorandum of Agreement
MPT	Mark Phillip Trust
MRA	Massachusetts Rifle Association
MSGRP	Multiple Source Groundwater Response Plan
NA	Not analyzed / Not applicable
NAS	Natural Attenuation Study
NAWQC	National Ambient Water Quality Criteria
NCP	National Contingency Plan
ND	Not detected
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPDWSA	Non-Potential Drinking Water Source Area
NPL	National Priorities List
NS	near shore sediments
O&M	operation and maintenance
OMEE	Ontario Ministry of the Environment and Energy

OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PAH	polynuclear aromatic hydrocarbons
Pb	lead
PCB	polychlorinated biphenyl compounds
PCE	tetrachloroethene
ppb	part per billion
PPE	personal protective equipment
ppm	part per million
PQL	Practical Quantitation Limit
PRB	permeable reactive barrier
PRG	Preliminary Remediation Goal
PRP	Potentially Responsible Parties
RAO	remedial action objective
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RCRA	Resource Conservation and Recovery Act
RME	reasonable maximum exposure
ROD	Record of Decision
RTC	(Anderson) Regional Transportation Center
SEL	severe effects level
SEM	selective extractable metals
SVOC	semi-volatile organic compound
SW	surface water
SY	square yard
TBC	To Be Considered

TCA	trichloroethane
TCE	trichloroethene / trichloroethylene
TCLP	Toxicity Characteristic Leachate Procedure
TDS	total dissolved solids
TNT	trinitro-toluene
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRV	toxicity reference value
TSS	total suspended solids
TtNUS	Tetra Tech NUS, Inc.
UCL	Upper Confidence Limit
μg/kg	microgram per kilogram
μg/L	microgram per liter
USFWS	United States Fish and Wildlife Service
VOC	volatile organic compound
XRF	X-ray Fluorescence (Spectroscopy)
ZVI	zero valent iron

E.0 EXECUTIVE SUMMARY

This report presents the findings of the Feasibility Study (FS) performed for the Industri-plex Superfund Site Multiple Source Groundwater Response Plan (MSGRP) Operable Unit 2 and including Wells G&H Superfund Site Aberjona River Study Operable Unit 3 (Study Area) located in Woburn, Massachusetts. This report relates the process used to evaluate a variety of approaches to address contaminated soil, groundwater, sediment, and surface water at the Site. This FS Report was prepared by Tetra Tech NUS, Inc. for the United States Environmental Protection Agency (EPA) under Work Assignment No. 116-RICO-0107, Contract No. 68-W6-0045.

E.1 Site Background

The Industri-plex Superfund Site (Industri-plex Site) is a 245-acre industrial park located in the northeast corner of Woburn, Massachusetts near the intersection of two major highways, I-93 and I-95 (Figure ES-1). The Industri-plex Site is bordered by two major interstate highways and by commercial and light industrial properties. The Aberjona River flows through a portion of the Industri-plex Site. Several associated tributaries, drainways, and wetlands also traverse or are situated on the Industri-plex Site. Currently, the Industri-plex Site is occupied by numerous active retail, commercial, and light industrial businesses.

From 1853 through 1931, the Industri-plex Superfund Site was home to various chemical manufacturing operations that principally produced chemicals for the local textile, leather and paper industries; the main products being sulfuric acid and related chemicals. Other chemicals produced at this facility included arsenic insecticides, acetic acid, dry colors, and organic chemicals including phenol, benzene, picric acid, toluene, and TNT. Beginning in 1935, the plant was dedicated to the manufacturing of glue from animal hides until mid-1969 when operations ceased and the property was vacated.

In December 1968, a private developer purchased portions of the chemical company property with the intent to develop the land into an industrial park to be called “Industri-plex 128”. From early 1970 to 1979, development activities involved filling and excavating portions of the property to facilitate the sale of various parcels. Excavations uncovered chemical and glue manufacturing wastes, including decaying animal hides. In addition to two existing waste stockpiles (i.e. East Central Hide Pile and South Hide Pile), some of these waste deposits were excavated and either trucked off site, buried on the southern Boston Edison Company (BECO) right-of-way, or stockpiled in two new waste piles (i.e. West and East Hide Piles).

The releases of metals and organic compounds at the Industri-plex Site have resulted in onsite soil contaminant levels that exceed those in background and offsite reference locations. The contaminants gradually dispersed into the surrounding environmental media and have resulted in the contamination of soil, groundwater, surface water, sediments, and biota.

The Industri-plex Site was listed on the Superfund National Priorities List in 1983, and in 1986, EPA completed a Record of Decision (ROD) that selected a cleanup remedy that included soil, air, and interim groundwater remedies. The soil remedy consisted of capping arsenic/lead/chromium contaminated soils and hide piles; the air remedy included construction of an impermeable cap and a gas collection and treatment system at the East Hide Pile; and groundwater was to be remediated in the interim through the construction of a treatment system for benzene and toluene “hot spot” areas. Institutional controls were considered a crucial part of the soil remedy to maintain the integrity of the cap into the future.

To fully understand the site-specific and area-wide groundwater issues, two additional studies were conducted; the Groundwater/Surface Water Investigation Plan (GSIP) to assess the Industri-plex Site related groundwater, surface water, and sediment contamination on site; and the Multiple Source Groundwater Response Plan (MSGRP) to evaluate area-wide contamination issues outside of the GSIP study area.

In 2002, EPA combined a similar surface water and sediment investigation being performed at the Wells G&H Superfund Site Aberjona River Operable Unit 3 into the MSGRP RI to more efficiently evaluate contamination and risk issues for the entire Aberjona River and ultimately develop one remedial decision for the river. As a result, the MSGRP RI Study Area for surface water and sediments was expanded to include the southern reaches of the Aberjona River from I-95-South, through the Wells G&H Site, to the Mystic Lakes (i.e. Southern Study Area). The MSGRP RI Study Area is also illustrated on Figure ES-1. The following sections briefly describe the findings of the comprehensive MSGRP RI.

E.2 Summary of Findings of the MSGRP RI

The MSGRP RI Study Area is divided into reaches based on similarity of habitat, species, and accessibility, which are shown on Figure ES-2 and are generally described as follows:

MSGRP RI STUDY AREA		
NORTHERN STUDY AREA	Reach 0	Industri-plex Site, northern section of Aberjona River, and the HBHA Pond and Wetlands south to I-95.
SOUTHERN STUDY AREA	Reach 1	From I-95, south to Salem Street, including the Wells G&H wetlands
	Reach 2	Salem Street south to the river crossing at Washington Street in Winchester, including the Cranberry Bog Conservation Area
	Reach 3	Washington Street south to Swanton Street, including Davidson Park
	Reach 4	Swanton Street south to Mill Pond in Winchester center
	Reach 5	Mill Pond outlet south to Upper Mystic Lake inlet
	Reach 6	Upper Mystic Lake, including upper and lower forebays, and Lower Mystic Lake to the Mystic River.

The following sections describe the significant findings of the environmental investigations conducted as part of the MSGRP RI.

E.2.1 Significant Contaminant Sources

Heavy metals are the principal contaminant of concern throughout both the Northern and Southern Study area, with arsenic representing the most significant metal present at elevated concentrations throughout the system. The most significant source of metals contamination in both the Northern and Southern Study Areas has been from the Industri-plex Superfund Site. Historical releases include releases from surface water, sediment and soil since operations began in the 1850s until the protective remedial cap was implemented in the mid 1990s (the Aberjona River flowed through the middle of the Industri-plex Site until the 1970s when it was redirected along Commerce Way), as well as historical groundwater releases. Although the contaminated soils have been capped, they continue to impact Site groundwater which is discharging to the HBHA Pond, and Aberjona River. Once discharged to the surface water bodies, sediments are impacted and the contaminants continue transport further downstream as part of the suspended solid load or in the dissolved state through diffusion processes. Current releases include releases from groundwater, sediment and soil (total suspended solids) and sediment diffusion (dissolved arsenic).

Several organic contaminants were detected in soils and groundwater in the Northern Study Area. However, benzene was the most frequently detected VOC at concentrations exceeding the MADEP GW-2 and GW-3 standards for groundwater. The highest concentrations of benzene were observed in the shallow groundwater in two areas of the site: between the East Central Hide Pile and the South Hide Piles; and within a localized area along the eastern edge of the West Hide Pile. High concentrations of benzene were observed in the deeper groundwater extending from the southern side of Atlantic Avenue to the central portion of the HBHA Pond. In general, the overall benzene plume, extending in both the shallow and deeper groundwater, is located in the vicinity of Atlantic Avenue south to the HBHA Pond. These plumes were found to discharge into the HBHA Pond.

Other organic compounds, such as naphthalene and trichloroethene (TCE), were also observed sporadically in groundwater samples in the vicinity of the HBHA Pond. TCE was also observed in another area approximately 0.5 mile south of the Site, generally located south and southwest of Cabot Road, in the vicinity of the former Mishawum Lake. However, based on the available groundwater data, it appears that the source of the TCE south of Cabot Road is not related to the Site.

E.2.2 Contaminant Migration

The fate and transport of contaminants involve complicated and interdependent processes that affect the mobilization of contaminants between various media and from reach to reach with the MSGRP RI Study Area. The principal source of contamination within the MSGRP Study Area is the soils underlying the Industri-plex Site. These contaminated soils are impacting groundwater, which in turn discharge to the HBHA Pond and wetlands and northern portions of the Aberjona River, subsequently impacting surface water. The surface water flows from the HBHA and Aberjona River combine at Mishawum Road and represents the primary contaminant transport vehicle for downgradient receptors. While the applicable fate and transport processes are generally the same throughout the Study Area, the impacted media and contaminants of concern vary from the northern portions of the Study Area to the lower portions of the Study Area and are summarized as follows:

ABERJONA RIVER SECTION	IMPACTED MEDIA	CONTAMINANTS OF CONCERN
Reach 0 (Industri-plex Site and the HBHA)	Soils, Groundwater, Sediment, Surface water	VOCs, SVOCs, Metals
Reach 1 (38-acre Wells G&H wetland)	Sediment, Surface water, Groundwater	Metals
Reach 2 to Reach 6 (Cranberry Bog Conservation Area to the Mystic Lakes)	Sediment, Surface water	Metals

The primary groundwater and surface water migration pathways are illustrated in Figure ES-3.

Leaching is the most significant ongoing transport process for metals in soils underlying the Industri-plex Site and impacting groundwater. Once in groundwater, contaminants continue to migrate via advection, diffusion, and dispersion processes. Significant contaminants found in groundwater include arsenic, benzene, toluene, and to a lesser degree lead and zinc. Once in the groundwater, contaminants are transported through groundwater flow paths and are predominantly discharged to the northern portions of the HBHA Pond, impacting sediments and surface water.

Constructed as a storm water management system during the early 1970s, the HBHA Pond is a large rectangular open surface water body at the northern end of the HBHA which receives groundwater discharges directly from the Industri-plex Site. The HBHA Pond is unique in that, due to the presence of a specific conductance chemo-cline induced by inputs of reduced groundwater originating from the Industri-plex Site and oxygenated surface water from Halls Brook, dissolved metals in groundwater are being partially sequestered in the HBHA Pond sediments. This chemocline also supports the biodegradation of benzene contaminants that are also being discharged by groundwater originating from the Industri-plex Site. As a result of the chemocline, high concentrations of dissolved arsenic and benzene and high conductivity are detected in deeper portions of the pond's surface water, while very low concentrations are in the shallow surface water.

These attenuation processes however, are incomplete and some metals, primarily arsenic and iron, are being released into surface water as part of the suspended sediment load or in the dissolved state. These releases are occurring during both baseflow and storm flow conditions.

During storm flow conditions however, the chemo-cline is destabilized and the amount of metals entering the water column and being transported further downstream is much greater. EPA studies have shown that it may take as long as 1 month to restore the chemo-cline in the HBHA Pond after a significant storm event. Although surface water data have generally not identified metals exceeding National Ambient Water Quality Criteria (NAWQC) standards, except in the deeper surface water at the HBHA Pond, the mass of metals represent a source of contamination to downstream depositional areas.

Although organic contaminants have been found to naturally attenuate in the water column either through dilution, biodegradation, or chemical degradation, heavy metals were found to migrate further downstream. Depending on the geochemical and flow conditions, dissolved metals in the water column may absorb to suspended solids, such as fine grained soil particles or other metal complexes and either precipitate and become part of the sediment bed load or be transported further downstream as part of the suspended solid load within the water column and be deposited at locations downstream. As part of the sediment bed load and depending on the geochemical conditions, metals may dissolve from the sediment particle back into the surface water column, whereby the cycle of dissolution and precipitation would continue. This cycling was mostly observed within portions of the HBHA that exhibited significant anoxic/reduced conditions, specifically, within the HBHA Pond. However, whereas wetlands in general typically exhibit reduced conditions or present a significant source of sulfides under oxic conditions, this cycling may be occurring in other portions of the MSGRP Study Area such as the Wells G&H wetlands.

The surface water investigation has shown that the metal concentrations are greater in the Northern Study Area (north of I-95 – Reach 0) and progressively decrease as the river continues south to the Mystic Lakes, which is essentially the final depositional area for these metals. Arsenic was the most prevalent metal observed in surface water throughout the entire study area of the river. The most significant declines were observed between the HBHA outlet and the Wells G&H wetlands outlet indicating deposition of suspended solids to the sediment bed.

Sediment samples also follow a similar trend in that the highest concentrations of metals were detected in depositional areas in the northern reaches of the Aberjona River, specifically in the HBHA (Reach 0), the Wells G&H wetlands (Reach 1), and the Cranberry Bog Conservation

Area (northern part of Reach 2). These data suggest that the metals originating from the Northern Study Area (i.e. HBHA Pond and wetlands) are being deposited in downstream wetland areas or quiescent sections of the river.

E.3 Risk Assessments

The data collected during this investigation was evaluated for potential human health and ecological risks. Separate baseline risk assessments were completed for the Northern Study Area and the Southern Study Area. The results of these assessments have been evaluated, combined and refined into a comprehensive risk evaluation for the Industri-plex Site and the entire Aberjona River and presented in the MSGRP RI Report. The following sections summarize the findings of the comprehensive risk evaluations.

E.3.1 Summary of Human Health Risks

The potential non-carcinogenic hazards and carcinogenic risks were estimated for adults and/or children assumed to contact contaminants in surface water, sediment, sediment cores, fish tissue, soil, groundwater, and soil gas. Cumulative receptor risks and hazards, summed across all applicable media and pathways for each exposure area, were estimated and compared to the target cancer risk range and non-carcinogenic target hazard index established by EPA for the protection of human health. As identified in the baseline human health risk assessments and supported by EPA, the following table summarizes the contaminants, media, and locations exceed risk management guidelines established for human exposures (refer to Figure ES-4 for sediment and soil locations and Figure ES-5 for monitoring well locations):

HUMAN HEALTH RISK			
RISK AREA	**SCENARIO/ RECEPTOR**	**IMPACTED MEDIA**	**MAJOR CONTAMINANT CONTRIBUTING TO RISK**
Industri-plex Site (Reach 0)	Future Construction Worker	Groundwater	(NC) - Arsenic
Industri-plex Site / HBHA Pond Area (Reach 0)	Future Industrial Worker	Groundwater, Indoor air	(NC) - Benzene, naphthalene, arsenic (C)- Trichloroethene
Former Mishawum Lake & South of Cabot Road Area (Reach 0)	Future Industrial Worker	Groundwater, Indoor air	(C)- Trichloroethene

HUMAN HEALTH RISK			
RISK AREA	**SCENARIO/ RECEPTOR**	**IMPACTED MEDIA**	**MAJOR CONTAMINANT CONTRIBUTING TO RISK**
Industri-plex Site / HBHA Pond Area (Reach 0)	Future Car Wash Worker	Indoor air	(C)- Trichloroethene (NC) - Benzene, naphthalene
Former Mishawum Lake & South of Cabot Road Area (Reach 0)	Future Car Wash Worker	Indoor air	(C)- Trichloroethene
Wells G&H Wetland (Reach 1); and Former Cranberry Bog (upper Reach 2)	Current/ Future Recreational Exposure	Sediment	(C) – Arsenic (NC) - Arsenic
HBHA (Reach 0); and Wells G&H Wetland (Reach 1)	Future Dredger/ Construction Worker	Sediment	(NC) – Arsenic
Former Mishawum Lake Area (Reach 0)	Future Day Care Child (surface soil)	Soil	(C) – Arsenic
	Future Day Care Child (subsurface soil)	Soil	(C) – Arsenic
	Future Const. Worker (subsurface soil)	Soil	(NC) - Arsenic

(NC) – Non-carcinogenic Hazard (C) – Carcinogenic Risk

E.3.2 Summary of Ecological Risks

Comprehensive studies were conducted to estimate potential risks to ecological receptors throughout the study areas, exposed to contaminants in surface water, sediment, soil, and biota.

Receptor populations or communities included representative mammals, birds, fish, and invertebrates. Based upon the evaluation conducted under this Baseline Ecological Risk Assessment Summary for the combined study areas, and supported by EPA, significant ecological risks are present in the HBHA Pond within Reach 0 of the Northern Study Area immediately downstream of the current Industri-plex Superfund Site boundaries. These significant risks were primarily associated with metals contamination, particularly arsenic, in the sediment and their toxicological effects on the benthic invertebrate community (see Figure ES-4).

Risks to aquatic organisms are also associated with observed high concentrations of benzene and dissolved arsenic in the deep water of the HBHA Pond. Dissolved arsenic concentrations were measured significantly above NAWQC values for aquatic life. These risks are consistent with the observed impairment of benthic invertebrates in the deep water of the HBHA Pond. These significant risks are considered unacceptable ecological risks to the HBHA Pond.

Risks to receptors downgradient of HBHA Pond are low. These include the low risks to benthic invertebrates and herbivorous mammals associated with high concentrations of arsenic in sediment. These low risks are not considered unacceptable ecological risks to ecological communities in the HBHA Wetlands, Wells G&H 38-acre wetland, and Former Cranberry Bog.

E.4 Feasibility Study Objectives

The objective of the FS is to develop and evaluate alternatives that address contaminated media in the MSGRP Study Area. The general FS process consists of the following general steps:

- Identify the media that require remedial actions.
- Develop remedial action objectives (RAOs) for each media of concern that are protective of human health and the environment.
- Develop general response actions for groundwater that define measures that may be taken singly or in combination to satisfy the RAOs for the MSGRP Study Area. Identify the volumes or areas of media to which the general response actions might be applied.
- Identify and screen the technologies applicable to each general response action.
- Develop and evaluate remedial alternatives to address the RAOs. The alternatives use different combinations of general response actions and technology types to provide different levels of risk reduction.

E.5 Identification of the Media of Concern

Identification of the media of concern for the site was based on the results of the RI and the site-specific human health and ecological risk assessments. The risk assessments identified unacceptable human health risks and hazards associated with soil located in the former Mishawum Lake area, with groundwater generally located in the vicinity of the Industri-plex Site and HBHA Pond area, with sediments located in near shore depositional areas in the Wells G&H wetland and the Cranberry Bog Conservation Area, and with deep sediments located in sections of the HBHA wetlands and the Wells G&H wetlands. Unacceptable ecological risks were associated with sediments and deep surface water in the HBHA Pond.

E.6 Remedial Action Objectives

The RAOs were formulated to be protective of human health and the environment. The RAOs were developed considering the identified risks, contaminants of concern, and the preliminary remediation goals developed for the MSGRP Study Area and are as follows:

Soil

The soil RAO for protection of human health is:

- Prevent exposures associated with an incremental lifetime cancer risk greater than 10^{-6} to 10^{-4} and or a HI greater than 1 by meeting the associated PRGs for the following scenarios:
  - Ingestion and dermal contact of arsenic by children at a future day care center for surface and subsurface soil within the former Mishawum Lake bed area and
  - Ingestion and dermal contact of arsenic by a future excavation worker for subsurface soil within the former Mishawum Lake bed area.

Groundwater

The groundwater RAOs for the Industri-plex Site/HBHA Pond area for the protection of human health are:

- Prevent exposures associated with an ILCR greater than 10^{-6} to 10^{-4} and/or HI greater than 1 by meeting the associated PRGs for the following scenarios:
  - Ingestion, dermal contact, and/or vapor inhalation of arsenic, benzene, naphthalene, trichloroethene, and 1,2-dichloroethane by an industrial worker using groundwater as process water,
  - Ingestion and dermal contact of arsenic by an excavation worker, and
  - Vapor inhalation of benzene, naphthalene, trichloroethene, and 1,2-dichloroethane by a car wash worker using groundwater in the job.

The groundwater RAO for protection of the environment addresses groundwater discharges to the HBHA Pond and its impact on surface water, and is as follows:

- Protect benthic invertebrates and aquatic life from exposure to levels of benzene and arsenic indicative of impairment due to groundwater discharges or provide alternative habitat (HBHA Pond only in the event that the HBHA Pond is used as a component of the remedy).

<u>Sediment</u>

The following sediment RAOs were developed for the protection of human health:

- Prevent exposures to sediment associated with an ILCR greater than 10^{-6} to 10^{-4} and/or HI greater than 1 by meeting the associated PRGs for the following scenarios:
  - Ingestion and dermal contact of accessible arsenic and benzo(a)pyrene for current and future recreational land use at the Wells G&H wetland stations WH, NT-3, and 13/TT-27,
  - Ingestion and dermal contact of accessible arsenic for current and future recreational land use at the Cranberry Bog Conservation Area station CB-03, and
  - Ingestion and dermal contact of arsenic for future dredging workers at sediment core locations SC02 (HBHA wetland) and SC05, SC06, and SC08 (Wells G&H 38-acre wetland).
- Minimize to the extent practicable, the migration of soluble and particulate arsenic during storm events to downstream depositional areas.

The following RAO was developed to address ecological risks in the HBHA Pond due to contamination in sediment:

- Protect benthic invertebrates from toxicological impacts indicative of impairment as compared to reference habitats or provide alternate habitat in the event that the HBHA Pond is used as a component of the remedy. Meet ARARs for the protection of aquatic life.

<u>Surface Water</u>

The following RAO was developed address ecological risks in the HBHA Pond due to contamination in the deep surface water:

- Protect aquatic life from arsenic and benzene above levels indicative of impairment or provide alternate habitat. Meet ARARs for the protection of aquatic life.

E.7 <u>Remedial Action Alternatives Summary</u>

Twenty seven remedial alternatives were developed to address the RAOs for the specific media of concern and were based on the environmental setting where the specific medium was located. These areas present unique challenges in addressing the contamination problems and typically require different methods and approaches to meet the RAOs. For example sediments requiring remediation are located in three distinctly different areas that include: in a large open water pond (HBHA Pond); in shallow wetland areas where the water depth is generally less than 2 feet deep (near shore sediments of the Wells G&H wetland and the Cranberry Bog Conservation Area); and in buried deep sediments in deeper wetland areas of the river or stream channel in the HBHA wetlands and the Wells G&H wetlands. Remedial alternatives developed for one type of sediment may not be practical or feasible for another.

These 27 alternatives were formulated by combining technologies and general response actions retained following a screening evaluation of 72 technologies for effectiveness, implementability, and cost. Although the alternatives are media-specific, in most-cases, the media and alternatives are inter-related such that one alternative for a particular medium may impact the remedial alternative options for other downgradient media. For example, since contaminated groundwater discharges are responsible for sediment contamination in the HBHA Pond, any sediment alternative would be dependent upon the actions taken to eliminate the groundwater sources of contamination otherwise the sediment remedy could become re-contaminated.

The 27 alternatives that were selected for detailed analysis and evaluation in the FS are briefly described below by media:

<u>Surface Soil (0 to 3 feet below grade) in the former Mishawum Lake bed area – (SS)</u>:

- Alternative SS-1: No Action
    - o A baseline alternative to which other surface soil alternatives may be compared. No remedial actions are taken under this alternative.
- Alternative SS-2: Institutional Controls with Monitoring
    - o Provides protection of human health by controlling potential exposures to contaminated soil through the implementation of institutional controls whereby use of the properties for a day care facility would not be allowed. Excavations without regulatory oversight and adequate worker health and safety precautions

would also be prohibited. This alternative includes a groundwater monitoring component to ensure that contaminated soils left in-place do not impact groundwater and create an unacceptable risk or hazard in the future.

- Alternative SS-3: Permeable Cover and Monitoring with Institutional Controls
  - o Provides protection of human health by preventing or controlling potential exposures to contaminated soil through the construction of a protective barrier or cap over the contaminated soils. In addition, institutional controls would be required to ensure that the cover is protected through deed restrictions or other appropriate institutional controls and maintenance. This alternative includes a groundwater monitoring component to ensure that contaminated soils left in-place do not impact groundwater and create an unacceptable risk or hazard in the future.
- Alternative SS-4: Excavation and Off-Site Disposal
  - o All surface soils exceeding the arsenic PRG will be excavated and transported offsite for disposal at an approved, licensed facility. This alternative would provide permanent elimination of risks to human health resulting from future exposures to arsenic in surface soils.
- Alternative SS-5: Excavation, Treatment, and On-Site Reuse
  - o All surface soils exceeding the arsenic PRG will be excavated, treated onsite to remove arsenic, and then placed back into the excavations. No offsite disposal of wastes would be required except for those wastes generated during the treatment process (i.e. contaminated rinsate). This alternative would provide permanent elimination of risks and hazards to human health resulting from future exposures to arsenic in surface soils.

<u>Subsurface Soil (3 to 15 feet below grade) in the former Mishawum Lake bed area - (SUB)</u>*:*

- Alternative SUB-1: No Action
  - o A baseline alternative to which other subsurface alternatives may be compared. No remedial actions are taken under this alternative.
- Alternative SUB-2: Institutional Controls with Monitoring
  - o Provides protection of human health by controlling potential exposures to contaminated subsurface soil through the implementation of institutional controls whereby excavations would be prohibited without regulatory oversight and adequate worker health and safety precautions. This alternative includes a

groundwater monitoring component to ensure that contaminated soils left in-place do not impact groundwater and create an unacceptable risk or hazard in the future.

- Alternative SUB-3: Permeable Cover and Monitoring with Institutional Controls
  - o Provides protection of human health by preventing or controlling potential exposures to contaminated subsurface soil through the construction of a protective barrier or cap over the contaminated soils. In addition, institutional controls would be required to ensure that the cover is protected through deed restrictions or other appropriate institutional controls and maintenance. This alternative includes a groundwater monitoring component to ensure that contaminated soils left in-place do not impact groundwater and create an unacceptable risk or hazard in the future.

<u>Groundwater - (GW)</u>

- Alternative GW-1: No Action
  - o A baseline alternative to which other groundwater alternatives may be compared. No remedial actions are taken under this alternative.
- Alternative GW-2: Pond Intercept with Monitoring and Institutional Controls
  - o Provides protection of human health by preventing or controlling potential exposures to contaminated groundwater through institutional controls to address potential human health risks and hazards associated with direct contact, inhalation, and ingestion exposures by preventing groundwater withdrawals. GW-2 also controls the downstream migration of contaminated groundwater to areas in the HBHA wetlands and the Aberjona River by intercepting contaminant plumes at the HBHA Pond where natural processes can degrade or sequester the contaminants.
- Alternative GW-3: Plume Intercept by Groundwater Extraction, Treatment and Discharge and Monitoring with Institutional Controls
  - o Provides protection of human health by preventing or controlling potential exposures to contaminated groundwater through institutional controls to address potential human health risks and hazards associated with direct contact, inhalation, and ingestion exposures by preventing groundwater withdrawals. This alternative is an active groundwater extraction and treatment alternative that consists of a groundwater extraction system that would intercept and treat groundwater contaminant plumes prior to their discharge into the HBHA Pond thus preventing the continued discharge of groundwater contaminants into the

HBHA Pond and preventing the continued migration of contaminants through surface water and sediments to areas downstream. In addition, GW-3 incorporates in-situ bio-enhancement treatment through oxygen injection to treat benzene at the West Hide Pile.

- Alternative GW-4: Plume Intercept by In-Situ Groundwater Treatment and Monitoring with Institutional Controls
  - o Provides protection of human health by preventing or controlling potential exposures to contaminated groundwater through institutional controls to address potential human health risks and hazards associated with direct contact, inhalation, and ingestion exposures by preventing groundwater withdrawals. GW-4 is an in-situ groundwater treatment alternative that incorporates two technologies to address both organic and inorganic contaminants in groundwater. First, in-situ bio-enhancement treatment through oxygen injection would be used to treat the source areas for organic contaminants (benzene, TCE, 1,2-DCA, and naphthalene) located between the East-Central Hide Pile and the South Hide Pile in the vicinity of Atlantic Avenue and at the West Hide Pile for benzene. Second, a permeable reactive barrier (PRB) located between the southern perimeter of the NSTAR (formerly Boston Edison) right-of-way and the HBHA Pond would be constructed for the treatment and removal of arsenic. GW-4 would intercept and treat arsenic contaminated groundwater prior to its discharge into the HBHA Pond thus preventing the continued discharge of groundwater contaminants into the HBHA Pond and preventing the continued migration of contaminants through surface water and sediments to areas downstream.

<u>HBHA Pond Sediments - (HBHA)</u>

- Alternative HBHA-1: No Action
  - o A baseline alternative to which other HBHA Pond sediment alternatives may be compared. No remedial actions are taken under this alternative.
- Alternative HBHA-2: Monitoring
  - o Provides for long-term monitoring to evaluate possible changes to the nature and extent and migration patterns of contamination and risks to benthic invertebrates over time as a result of natural degradation or attenuation processes. HBHA-2

relies on a groundwater alternative to eliminate contaminated groundwater discharges to be protective.

- Alternative HBHA-3: Subaqueous Cap
    - o Provides protection of the environment from contaminated sediments by preventing or controlling direct contact exposures to benthic invertebrates and migration of contaminated sediments to downstream areas through the installation of a protective barrier or cap over the contaminated sediments. The cap consists of a geotextile layer covered with clean permeable soil materials over contaminated sediments at the base of the HBHA Pond creating a new benthic habitat and an effective barrier from existing sediment contaminants. HBHA-2 relies on a groundwater alternative to eliminate contaminated groundwater discharges which could, over time, result in recontamination of the clean cap materials.
- Alternative HBHA-4: Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat
    - o Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) involves partial removal of contaminated sediments and reduces the migration of soluble and particulate arsenic released during storm events to downstream depositional areas. HBHA-4 divides the HBHA Pond into two main areas using a system of cofferdams: one area located in the northern part of the pond will be used to allow contaminated groundwater to discharge, maintain the chemo-cline to degrade and sequester dissolved contaminants, retain contaminated suspended sediments, and aerate the pond; and the second area, located in the southern section, would be dredged to remove contaminated sediments and restored. This alternative protects the environment by preventing exposure of benthic invertebrates to contaminated sediments in the southern portion of the pond and provides for an alternate habitat to mitigate the loss of habitat in the northern portion of the pond. Other key features and components of HBHA-4 include: diverting Halls Brook storm flow water downstream of the contaminated sediment retention area thus preventing re-suspension and migration during storm events; permanently removes contaminated sediments in the southern portion of the HBHA Pond that exceed the arsenic PRG and restores the southern portion; prevents arsenic-contaminated groundwater from discharging into the New Boston Street Drainway which eventually discharges to Halls Brook and the

HBHA Pond and prevents any associated contaminated sediment above the PRG from eroding into the northern portion of the HBHA Pond; and prevents arsenic-contaminated soils exceeding the HBHA Pond sediment PRG, located along the southern boundary of the Boston Edison right-of-way (A6 area), from eroding into the northern portion of the HBHA Pond and contributing to the contaminated sediment load in the system. Unlike other HBHA alternatives, HBHA-4 does not rely on groundwater alternatives to eliminate contaminated groundwater discharges since HBHA-4 incorporates natural processes and aeration to degrade and sequester groundwater contaminants as they are discharged into the pond.

- Alternative HBHA-5: Removal and Off-Site Disposal
    - o All sediments in the HBHA Pond exceeding the arsenic PRG will be dredged, dewatered, and transported offsite for disposal at an approved, licensed facility. This alternative would provide permanent elimination of risks to ecological receptors resulting from exposures to contaminated sediments in the HBHA Pond. In addition, a section of the New Boston Street Drainway would be lined with an impermeable barrier to prevent arsenic-contaminated groundwater from discharging into the New Boston Street Drainway, which eventually discharges to Halls Brook and the HBHA Pond, and prevent any associated contaminated sediment above the PRG from eroding into the HBHA Pond. Soils located along the southern boundary of the Boston Edison right-of-way (A6 area) would be capped to prevent arsenic-contaminated soils from eroding into the HBHA Pond and contributing to the contaminated sediment load in the system. HBHA-5 also relies on groundwater alternatives to eliminate contaminated groundwater discharges which could, over time, result in recontamination of the restored areas in the HBHA Pond.

<u>Near Shore Sediments in the Wells G& H Wetlands and the Cranberry Bog Conservation Area - (NS)</u>

- Alternative NS-1: No Action
    - o A baseline alternative to which other alternatives may be compared. No remedial actions are taken under this alternative.

- Alternative NS-2: Institutional Controls
    - o Provides protection of human health by preventing or controlling potential exposures to contaminated sediment through installation of fencing to restrict access and implementation of institutional controls. Institutional controls would take the form of deed restrictions or other appropriate institutional controls whereby land use would be restricted and excavations in this area would be prohibited unless adequate precautions (engineering controls, PPE) were taken to minimize or prevent direct contact with contaminated sediment during removal activities.
- Alternative NS-3: Monitoring with Institutional Controls
    - o Provides protection of human health by preventing or controlling potential exposures to contaminated sediment through installation of fencing to restrict access and implementation of institutional controls. Institutional controls would take the form of deed restrictions or other appropriate institutional controls whereby land use would be restricted and excavations in this area would be prohibited unless adequate precautions (engineering controls, PPE) were taken to minimize or prevent direct contact with contaminated sediment during removal activities. In addition, Alternative NS-3 incorporates long-term surface water and sediment monitoring to evaluate possible changes to the nature and extent and migration patterns of contaminated sediments in the near shore areas.
- Alternative NS-4: Removal and Off-Site Disposal
    - o All near shore sediments exceeding the arsenic PRG will be excavated and transported offsite for disposal at an approved, licensed facility. This alternative would provide permanent elimination of risks to human health resulting from future exposures to arsenic in near shore sediments.

<u>Deep Sediments in the HBHA Wetlands and in the Wells G& H Wetlands - (DS)</u>

- Alternative DS-1: No Action
    - o A baseline alternative to which other alternatives may be compared. No remedial actions are taken under this alternative.
- Alternative DS-2: Institutional Controls
    - o Provides for the protection of human health by preventing or controlling potential exposures to contaminated deep sediment through the implementation of institutional controls. Institutional controls would take the form of deed restrictions or other appropriate institutional controls whereby excavations in this area would be

prohibited unless regulatory oversight and adequate precautions (e.g. engineering controls, PPE, etc.) were taken to minimize or prevent direct contact with contaminated sediment during dredging activities.

- Alternative DS-3: Removal and Off-Site Disposal
    - All deep sediments exceeding the arsenic PRG will be excavated and transported offsite for disposal at an approved, licensed facility. This alternative would provide permanent elimination of risks to human health resulting from future exposures to arsenic in deep sediments.

<u>Deep Surface Water in the HBHA Pond (SW)</u>

- Alternative SW-1: No Action
    - A baseline alternative to which other alternatives may be compared. No remedial actions are taken under this alternative.
- Alternative SW-2: Monitoring
    - This alternative uses monitoring to evaluate the status of contamination that may or may not be attenuated by natural processes or other selected groundwater and sediment remedial alternatives. This alternative must be implemented in conjunction with other media-specific alternatives whereby the long-term effectiveness of the alternatives are evaluated and sources of contamination (i.e. groundwater discharges and arsenic dissolution from contaminated sediments) are monitored.
- Alternative SW-3: Monitoring and Providing an Alternate Habitat
    - This alternative uses monitoring to evaluate the status of contamination that may or may not be attenuated by natural processes or other selected groundwater and sediment remedial alternatives. To mitigate the loss of aquatic habitat within the affected area and meet the RAO, a similar wetland would be constructed to compensate for the wetland loss and to maintain the inventory of the benthic community within the watershed.

E.8 Comparative Evaluation of Remedial Alternatives

As part of the detailed analysis, comparisons of the remedial action alternatives within specific medium were made to identify differences between the alternatives and how site contaminant threats are addressed with regards to key elements of the seven evaluation criteria prescribed in the National Contingency Plan. These criteria include:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume Through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

A summary of the comparative analysis of the remedial alternatives, by media, for the threshold criteria and costs is presented in Table ES-1. These comparisons are discussed in detail in Section 4.3 and are summarized in Tables 4-28A through 4-28G.

1.0 INTRODUCTION

This report presents the findings of the Feasibility Study (FS) performed for the Industri-plex Superfund Site Multiple Source Groundwater Response Plan (MSGRP) Operable Unit 2 and including Wells G&H Superfund Site Aberjona River Study Operable Unit 3 (Study Area) located in Woburn, Massachusetts. This FS Report was prepared by Tetra Tech NUS, Inc. for the United States Environmental Protection Agency (EPA) under Work Assignment No. 116-RICO-0107, Contract No. 68-W6-0045. The report presents a range of remedial options that address potential risks to human health and the environment identified during the MSGRP Remedial Investigation (RI). The RI Report was submitted previously under separate cover.

This FS was prepared in accordance with the requirements of: the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986; the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) 40 CFR Part 300; and the Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA, October 1988) and direction received from EPA.

A Record of Decision (ROD) for the Industri-plex Site was signed in 1986, addressing on-site soil, sediment, and groundwater contamination. The RI/FS that supported the ROD focused on site-specific soil and groundwater "hot-spot" problems and did not attempt to identify other possible sources of either upgradient or cross-gradient groundwater contamination or impacts to surface water. The MSGRP RI (TtNUS, 2005) and this MSGRP FS evaluate area-wide soil, groundwater, surface water, and sediment contamination issues.

The remedial options developed in this document will be used by EPA to formulate a preferred remedy to address soil, groundwater, surface water, and sediment contamination throughout the Industri-plex MSGRP area. After a public comment period, the selected remedy will be documented in another EPA ROD.

1.1 Organization of Report

The FS is presented in one volume. Section 1.0 presents the purpose of the FS Report, a summary of the MSGRP Study Area, the history and former land use of the MSGRP Study Area properties, a discussion of the nature and extent of contamination, and results of the human health and ecological risk assessments. Section 2.0 presents the remedial action objectives, the general response actions, preliminary remediation goals, estimates of contaminated materials volumes, and the identification and screening of alternatives. Section 3.0 presents the development and detailed descriptions of remedial action alternatives, and Section 4.0 presents detailed and comparative analyses of remedial action alternatives.

1.2 Purpose of the Report

The overall objective of this FS is to develop and evaluate alternatives that address soil, groundwater, surface water, and sediment contamination which pose potential risks to human health and/or the environment throughout the MSGRP Study Area. The general FS process is described below:

- Develop remedial action objectives incorporating target cleanup goals that are protective of human health and the environment. The remedial action objectives specify the contaminants, media of interest, exposure pathways, and preliminary remediation goals. The preliminary remediation goals (numeric criteria) are developed based on chemical-specific applicable or relevant and appropriate requirements (ARARs), when available, and site-specific risk-related factors.

- Develop general response actions to address each medium of interest. Each response action may be implemented singly or in combination with other actions to satisfy the remedial action objectives.

- Identify and screen technologies applicable to each general response action. Technologies and process options that are not technically implementable are eliminated. Representative process options for the remaining technologies are then evaluated for their effectiveness, implementability, and cost.

- Assemble remedial alternatives from the retained technologies. The alternatives consist of a range of remedial technologies for source control and groundwater control.

- Prepare a detailed analysis of individual alternatives following the criteria specified in the NCP and the RI/FS guidance documents. Finally, compare and evaluate the alternatives.

The remedial action objectives (RAOs), presented in Section 2.2 of this FS Report, establish the site-specific criteria that are protective of human health and the environment, and comply with federal and state regulations, where applicable.

The general response actions, presented in Section 2.3 of this FS Report, establish the physical parameters, volumes, and physical settings for the contaminated media to be remediated, consistent with the RAOs.

Section 2.5 presents the identification and screening of technologies that will be considered to perform the soil, groundwater, surface water, and sediment remedial actions. Technologies retained in the initial screening then undergo a more detailed evaluation to identify processes best suited to achieve the remedial actions. The criteria used in evaluating technologies include: effectiveness of the technologies to address site-related contaminants, implementability of the technologies, and relative cost.

The rationale for developing remedial action alternatives is presented in Section 3.0. Technologies are assembled into alternatives representing a range of treatment and containment combinations. The alternatives are developed and refined at this stage by characterizing factors such as volumes or areas of contamination; interactions between media, sizing, and configuration of on-site treatment/containment systems; duration of activities; treatment rates; spatial requirements; distances to off-site treatment or disposal facilities; and regulations.

Detailed evaluations of each alternative were performed; the results are presented in Section 4.0. The alternatives were evaluated based on the following criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of mobility, toxicity, or volume through treatment; short-term effectiveness; implementability; and cost. Overall protection of human health and the environment and compliance with ARARs are the two threshold criteria, while the remaining five are balancing criteria. Community and state acceptance are the two modifying criteria that EPA will assess prior to final selection of the remedial alternative in the ROD. Comparative analyses of the alternatives are also presented in Section 4.0.

1.3 Background Information

This section provides a description of the MSGRP Study Area, its geology and hydrogeology, a summary of the Study Area's history, contaminant nature and extent, conceptual contaminant fate and transport, and comprehensive human health and ecological risk assessments.

1.3.1 Site Description and History

The Industri-plex Superfund Site (Site) is a 245-acre industrial park located in the northeast corner of Woburn, Massachusetts near the intersection of two major highways, I-93 and I-95 (Figure 1-1). The Site is bordered by these two highways and by commercial and light industrial properties. The Aberjona River flows through a portion of the Site. Several associated tributaries, drainways, and wetlands also traverse or are situated on the Site. The nearest residences are located approximately 4,000 feet to the north, approximately 1,000 feet to the east, approximately 2,500 feet to the west, and approximately 4,000 feet to the south of the Site. Approximately 34,000 people live within 3 miles of the Site. The Site is currently occupied by numerous active retail, commercial, and light industrial businesses as well as the Anderson Regional Transportation Center, a 33-acre commuter transportation hub, which was constructed on the Site in the late 1990s and opened in May 2001.

From 1853 through 1931, the Site was home to various chemical manufacturing operations that principally produced chemicals for the local textile, leather and paper industries; the main products being sulfuric acid and related chemicals. Other chemicals produced at this facility included arsenic insecticides, acetic acid, dry colors, and organic chemicals including phenol, benzene, picric acid, toluene, and 2,4,6-trinitrotoluene (TNT). Beginning in 1935, the plant was dedicated to the manufacturing of glue from animal hides until mid-1969 when operations ceased and the site was vacated. In December 1968, the Mark Phillip Trust (MPT) purchased approximately 149 acres of the property from Stauffer Chemical Company, while others purchased the remaining 35 acres. The MPT intended to develop the Stauffer land, along with land owned to the south and east, as an industrial park to be called "Industri-plex 128". From early 1970 to 1979, development activities involved filling and excavating portions of the property to facilitate the sale of various parcels. Excavations uncovered chemical and glue manufacturing wastes, including decaying animal hides. In addition to two existing waste stockpiles (i.e. the East Central Hide Pile and the South Hide Pile), some of these waste deposits were excavated and either trucked off site, buried on the southern Boston Edison Company (BECO) right-of-way, or stockpiled in two new waste piles (i.e. the West and East Hide Piles).

The releases of metals and organic compounds at the Industri-plex Site have resulted in onsite soil contaminant levels that exceed those in background and offsite reference locations. The contaminants gradually dispersed into the surrounding environmental media and have resulted in the contamination of soil, groundwater, surface water, sediments, and biota.

The Site was listed on the Superfund Interim List of 115 Top Priority Hazardous Waste Sites in 1981 and on the Superfund National Priorities List in 1983. In 1986, EPA completed a ROD that selected a cleanup remedy for the Site that included soil, air, and interim groundwater remedies. The soil remedy consisted of capping arsenic/lead/chromium contaminated soils and hide piles with concentrations of arsenic greater than 300 mg/kg, lead greater than 600 mg/kg, and chromium greater than 1,000 mg/kg. Institutional controls are considered a crucial part of the soil remedy to maintain the integrity of the cap into the future. The air remedy included construction of an impermeable cap and a gas collection and treatment system at the East Hide Pile. Groundwater was to be remediated in the interim through the construction of a treatment system for benzene and toluene “hot spot” areas. Due to technical delays and negotiations, the interim groundwater remedy was not implemented, so the only groundwater remedy for the Site will be the permanent remedy addressed in the upcoming ROD.

The remedial investigation that originally supported the 1986 ROD focused on Site-specific soil and groundwater “hot-spot” problems and did not attempt to identify other possible sources of either upgradient or cross-gradient groundwater contamination or impacts to surface water. To fully understand the site-specific and area-wide groundwater issues, the ROD and the Consent Decree assigned separate responsibilities to the Settling Defendants and the EPA to conduct two additional studies. The Settling Defendants were required to implement the ROD-prescribed Groundwater/Surface Water Investigation Plan (GSIP) to assess the groundwater, surface water, and sediment contamination on the Site. The GSIP study area focused on Site-related contaminants and included the Industri-plex Superfund Site and downstream areas to I-95

(Northern Study Area). The EPA was required to implement the MSGRP to evaluate area-wide contamination issues outside of the GSIP study area. The description of the selected interim-remedy for groundwater noted that the findings and conclusions of the MSGRP would be used to develop and implement a final remedy for on-site groundwater problems. These decisions would also be based in part on the findings of the GSIP investigations.

While the GSIP and MSGRP investigations were being conducted to assess contamination in and around the northern reaches of the Aberjona River, an investigation of the Wells G&H Superfund Site, located about 1 mile south of the Industri-plex Site, was being conducted, which included an EPA-led investigation of the surface water and sediment of the southern portion of the Aberjona River to the Mystic Lakes. In 2002, EPA combined the separate surface water and sediment investigations being performed at the two Superfund sites into one study to more efficiently evaluate contamination and risk issues for the entire Aberjona River and ultimately develop one remedial decision for the river, if necessary. As a result, the MSGRP RI Study Area for surface water and sediments was expanded to include the southern reaches of the Aberjona River from I-95-South, through the Wells G&H Site, to the Mystic Lakes (i.e. the Southern Study Area). It is important to note that the groundwater investigations for the MSGRP RI are limited to the general area surrounding and including the Industri-plex Site. Groundwater in the vicinity of the Wells G&H Superfund Site is currently being investigated, and in some areas remediated, as part of the Wells G&H Superfund Site cleanup program under the auspices of the EPA and MADEP.

Consequently, the MSGRP RI report presented and evaluated data from over 4,800 samples collected as part of the MSGRP RI investigation. Samples were collected from various media including soil, groundwater, surface water, sediment, soil gas, and various biota (both plant and animal). These sampling efforts were part of the investigations initially conducted for separate studies at the two Woburn, Massachusetts Superfund sites as described below:

- Industri-plex Superfund Site -- GSIP: Focused the investigation on groundwater, surface water, sediments, and soil at the Industri-plex Site and surrounding area, south to Mishawum Road and I-95; conducted in three separate phases from 1990 to 2004.

- Wells G&H Superfund Site -- Operable Unit 3 (OU-3), Aberjona River Study: Focused the investigation on surface water and sediment within the Aberjona River and its associated wetlands from I-95 south to the Mystic Lakes; conducted from 1995 to 2004.

- Industri-plex Superfund Site -- MSGRP: Incorporates the findings of the GSIP, Wells G&H OU-3 Aberjona River Study, Preliminary MSGRP – Industri-plex Study Area (1997), Preliminary MSGRP – Aberjona River Study Area (2002), and focused the investigation on area-wide groundwater, surface water, sediments, and soil contamination including areas adjacent to the Industri-plex Site, south to Mishawum Road and I-95, and at specific locations along the Aberjona River south of I-95; conducted from 2000 to 2004. The MSGRP also considered other relevant studies along the Aberjona River conducted by the Massachusetts Institute of Technology (MIT).

The MSGRP RI Study Area is located within the Aberjona River Watershed. The Aberjona River is the primary river system in the Aberjona River basin and has an approximate 65-square kilometer (km^2) drainage area. The river flows through Woburn and Winchester, Massachusetts terminating in Winchester where it discharges into the Mystic Lakes.

The most significant water bodies located in the northern part of the MSGRP RI Study Area include: Halls Brook, Halls Brook Holding Area (HBHA), and the Aberjona River. With the exception of Halls Brook, all of these water bodies were either modified or created for flood storage capacity during development of the area. Fed primarily by Halls Brook, the Halls Brook Holding Area (HBHA) was created as a storm water management area following the filling of Mishawum Lake in the 1970s. The northern portion of the HBHA consists of a large rectangular shallow pond (approximately 175 feet x 900 feet and depth up to 20 feet), referred to as the HBHA Pond. Downstream of the HBHA Pond, the southern portion of the HBHA consists of wetlands containing three smaller ponds. When the HBHA was constructed, the Aberjona River was diverted from Mishawum Lake to its current course which follows a series of culverts and drainage channels in the middle of Commerce Way that run parallel to the HBHA approximately 1,500 feet to the east. Flows from the Aberjona River and the HBHA converge at the outlet of the HBHA at Mishawum Road.

The entire Southern Study Area (the Aberjona River and its floodplains) lies within the 100-year floodplain; wetland areas adjacent to the Aberjona River are scattered throughout the Southern

Study Area. The most significant wetland areas include the Wells G&H wetland and the Cranberry Bog Conservation Area (CBCA) wetland. The low-lying areas along the river frequently experience flooding due to increased storm water contributions from developed and paved areas, causing the Aberjona River to exceed its flow capacity. The most significant water bodies include the Upper and Lower Mystic Lakes, where the Aberjona discharges.

The Aberjona River flows through urbanized sections of Woburn and Winchester. Both of these municipalities have an extensive industrial history, principally involving the tanning industry, dating back into the early 1800s. Historically, waste products from these industries were discharged into the Aberjona River and may have contributed to the historical contamination of the river's water quality and sediments.

The MSGRP RI Study Area is divided into reaches based on similarity of habitat, species, and accessibility. This concept was first introduced during the preparation of the baseline ecological risk assessment for the Aberjona River Study (OU-3) whereby the Aberjona River was divided into six reaches (1 through 6). For purposes of continuity, the same reaches were used in the human health risk assessment for the Aberjona River Study. When EPA decided to merge the MSGRP RI and Aberjona River Study investigations, the original six reaches were expanded to include "Reach 0", which represents the entire Northern Study Area. The study area reaches are shown on Figure 1-2 and are generally described as follows:

<table>
<tr><th colspan="3">MSGRP RI STUDY AREA</th></tr>
<tr><td>NORTHERN STUDY AREA</td><td>Reach 0</td><td>Industri-plex Site, northern section of Aberjona River, and the HBHA Pond and Wetlands south to I-95.</td></tr>
<tr><td rowspan="6">SOUTHERN STUDY AREA</td><td>Reach 1</td><td>From I-95, south to Salem Street, including the Wells G&H wetlands</td></tr>
<tr><td>Reach 2</td><td>Salem Street south to the river crossing at Washington Street in Winchester, including the Cranberry Bog Conservation Area</td></tr>
<tr><td>Reach 3</td><td>Washington Street South to Swanton Street, including Davidson Park</td></tr>
<tr><td>Reach 4</td><td>Swanton Street south to Mill Pond in Winchester center</td></tr>
<tr><td>Reach 5</td><td>Mill Pond outlet south to Upper Mystic Lake inlet</td></tr>
<tr><td>Reach 6</td><td>Upper Mystic Lake, including upper and lower forebays, and Lower Mystic Lake</td></tr>
</table>

Groundwater Classification

The Massachusetts Contingency Plan (MCP) defines all groundwater into one of three classes (GW-1, GW-2 and GW-3) and has established contaminant criteria applying to each classification. Groundwater is classified as GW-1 if it is located within a current or potential future drinking water source area. The GW-2 classification applies to areas where there is the potential for migration of vapors from the groundwater to the air inside occupied structures. Specifically, the GW-2 classification applies to groundwater located within a 30-foot radius of an existing occupied building or structure, where the average annual depth to groundwater in the area is 15 feet or less. The GW-3 classification applies to groundwater that may impact surface water. All groundwater is considered a potential source of discharge to surface water and therefore is, at a minimum, categorized as GW-3 (310 CMR 40.0932).

The groundwater classifications for the MSGRP Study Area were identified by MADEP and documented in their "Groundwater Use and Value Determinations" for the Industri-plex and Wells G&H sites. The MADEP "Groundwater Use and Value Determination" for the Industri-plex site (MADEP, 1997) concluded that the aquifer in the Northern Study Area was of low use and value. This determination was reaffirmed in a clarification issued by MADEP in March 2004 (Mayor, 2004). The determination and the clarification are included in Appendix 3C-1 of the MSGRP RI.

The MADEP concluded that, with the exception of two small areas that may be classified as GW-1 (Phillip's Pond and south of the easternmost extension of the NSTAR [formerly BECO] ROW), the Northern Study Area aquifer was classified as a Non-Potential Drinking Water Source Area (NPDWSA) because of its concentrated industrial development. MADEP concluded that a low use and value determination was appropriate for the entire area despite the presence of the two potential GW-1 areas because commercial development and other factors make it unlikely that public drinking water facilities would be developed in the areas (Mayor, 2004).

Due to its designation as a low use and value NPDWSA, the MADEP concluded that for the purposes of the risk assessment, the groundwater in the Northern Study Area is classified as GW-2 and GW-3. The GW-2 classification applies to any areas where there are occupied structures and the average depth to groundwater is 15 feet or less. The GW-3 classification applies to the entire study area.

As indicated in the following paragraph, northern boundary of the Interim Wellhead Protection Area (IWPA) for Woburn municipal Wells G&H is approximately located at Interstate 95, which is the approximate southern boundary of the Northern Study Area. Although the wells are inactive, they are still considered a public water supply and the MCP requires that groundwater flowing into an IWPA must meet state drinking water standards (GW-1 criteria). Therefore, although the Northern Study Area groundwater is classified as GW-2/GW-3, the groundwater at its southern border should meet GW-1 standards before entering the IWPA.

The MADEP "Groundwater Use and Value Determination" for the Wells G&H Superfund Site (MADEP, 2004) concluded the aquifer in the area of the Wells G&H site (Southern Study Area) is of <u>medium</u> use and value. The use and value determination report is included in Appendix 3C-2 of the MSGRP RI. Nearly the entire Wells G&H site, including the 38-acre wetlands, lies within the IWPA of municipal wells G and H. An IWPA is defined as the area within a one-half mile radius of a public water supply that does not have a delineated Zone II (Zone II, as defined in the 2001 MADEP Groundwater Source Approval Regulations, is the area of an aquifer which contributes water to a well under the most severe pumping and recharge conditions that can be realistically anticipated). Although the wells are inactive, they are still considered a public water supply.

Because the Wells G&H aquifer is within the IWPA and because it is a medium and high yield aquifer, the site area aquifer is classified under the MCP as a GW-1 area. The one half-mile radius of the IWPA takes precedence over areas excluded as non-drinking water source areas under the MCP; therefore, regardless of other designations, the entire area within the IWPA is considered a current drinking water source area (MADEP, 2004). Due to the development in the area, the GW-2 classification also potentially applies to most of the remaining potions of aquifer (MADEP, 2004). Lastly, at a minimum, all groundwater is considered as GW-3 as the aquifer is expected to discharge into a surface water.

1.4 Nature and Extent of Contamination

The MSGRP remedial investigation was conducted to delineate the nature and extent of contamination at the MSGRP Study Area and how this contamination may be migrating in the environment. Detailed assessments are presented in the MSGRP Remedial Investigation Report (TtNUS, 2004). Summaries of the RI findings are presented below.

1.4.1 Summary of Soil Contaminant Nature and Extent

The nature and extent of soil contamination was further investigated in areas within, adjacent to, and downgradient of the Industri-plex Site. These areas included soils along the perimeter of the Industri-plex Site boundary, buried sediments of the former Mishawum Lake bed, benzene and toluene source area soils, and floodplain soils along the HBHA and the Aberjona River. Soils impacted by site-related contaminants are as follows:

- There are over 150 acres of soils at the Industri-plex Site that are contaminated with heavy metals, specifically: arsenic, lead, chromium, and to a lesser degree, barium, copper, zinc, and mercury. Approximately 110 acres exceeded the heavy metals threshold values established in the 1986 Industri-plex Site ROD and have been capped with either an engineered cover or with existing materials considered to be "equivalent cover" (e.g. asphalt pavement, building slabs, etc.) At the time the ROD was prepared, other alternatives had been evaluated including complete removal of the soils. However, removal was considered financially infeasible (greater than $245 million) due to the large volume of soils that would require remediation, which would also present significant technical challenges due to site conditions. (Roux, 1984). Although capped and no longer a threat from erosion, these contaminants remain onsite and represent the most significant source of contamination in the MSGRP RI Study Area. Some of these chemicals have remained adsorbed to soils while others have been mobilized into deeper soils, into groundwater, and into the adjacent wetlands, HBHA and Aberjona River.

- Four areas located outside and adjacent to the Industri-plex Site boundary were investigated to determine if metals contamination exceeding the Industri-plex soil remedy action levels extended beyond the Site boundary. Only the area located between the southern Site boundary and the HBHA Pond (Area 6) was found to contain concentrations of arsenic, chromium, and lead exceeding action levels established for the Industri-plex Site Soil Remedy.

- Prior to its being filled to create open land for development, Mishawum Lake would have served as one of the first significant depositional areas for contaminants being discharged from the Industri-plex Site. Concentrations of volatile organic compounds (VOCs) and semi volatile organic compounds (SVOCs) in soils were only sporadically detected in subsurface soils and at low concentrations which did not exceed regulatory screening criteria (i.e. Region 9 preliminary remediation goals [PRGs]). Soils exhibiting concentrations of metals exceeding comparative regulatory criteria (i.e. Region 9 PRGs and MADEP Soil Background criteria) were detected in both near-surface and subsurface soils. The highest concentrations of metals and most frequent exceedances for metals, in particular arsenic, generally occurred in the soil samples collected at a depth representing the former lake bottom.

- An investigation was conducted to locate the source of persistent benzene and toluene groundwater contamination located adjacent to the West Hide Pile (benzene) and along Atlantic Avenue (benzene and toluene). This investigation included subsurface geophysical surveys (i.e., ground penetrating radar and electro-magnetic surveys), soil-gas sampling, subsurface soil samples, and groundwater sampling. Although a concentrated source of contamination was not located (e.g., underground storage tanks (UST), drums, etc.) both benzene and toluene were detected in most soil samples. However, these detections were generally low, with the majority of samples well below the comparative screening criteria. At sample locations collected along Atlantic Avenue, only 4 of 17 samples exceeded the Region 9 PRGs for benzene (600 µg/kg - residential) and none exceeded the Region 9 PRG for toluene (520,000 µg/kg - residential). In addition, one soil sample collected at the West Hide Pile within the saturated zone exhibited elevated concentrations of benzene (210,000 µg/kg) exceeding the Region 9 PRG criterion.

- Soil samples were collected in depositional areas along the HBHA and the Aberjona River to investigate the presence of heavy metals deposited by floodwaters. Areas investigated included the banks of a drainage channel along the BECO right-of-way in the southern portion of the Site, floodplain areas along the eastern and southwestern banks of the HBHA, wetlands north of the Wells G&H wetland area at Normac Road, the backyard of a residence located on Salem Street at the southwest edge of the Wells G&H wetland, the Cranberry Bog Conservation Area, Danielson Park, river bank/wetland areas at Kraft Food, Davidson Park in Winchester, and the banks of the Aberjona River near the Wedgemere train station in Winchester. Arsenic was the only metal that was detected in all floodplain sample locations at concentrations ranging from 6.1 mg/kg to 272 mg/kg. Arsenic concentrations exceeded Region 9 PRGs in all areas (except at the Wedgemere station where the criterion was exceeded in seven of nine samples). Although the Region 9 PRG for arsenic (0.39 mg/kg) is based on residential assumptions, approximately 87 percent of floodplain soil samples exhibited arsenic concentrations that also exceeded the MADEP Natural Soil Background reference criterion (20 mg/kg).

1.4.2 Summary of Groundwater Contaminant Nature and Extent

Between 1990 and 2002 over 460 groundwater samples were collected, analyzed, and quantitatively evaluated to assess area-wide groundwater contamination in the Northern Study Area. The findings are as follows:

- Arsenic was more frequently detected in groundwater than any other metal (detected in 360 samples out of 467 samples analyzed for metals). Approximately 12 percent of the samples where arsenic was detected exceeded the MADEP GW-3 standard (400 µg/L). Arsenic concentrations were generally highest in the groundwater south and west of the East Central Hide Pile and beneath the BECO right-of-way, with the maximum observed concentration of 24,400 µg/L located in the BECO right-of-way, just northwest of the HBHA.

- Other metals that exceeded the GW-3 standard included:

  - cadmium: only exceeded in three samples; the highest concentration only slightly exceeding the GW-3 criterion was located just north of the East Central Hide Pile

- chromium: only exceeded in two samples collected from the same well located approximately 450 feet south of Atlantic Avenue (likely attributed to high suspended solids in the sample)

- lead: exceeded in 23 samples; all located in the areas north of the Halls Brook Holding Area pond, east of New Boston Road, and west of Atlantic Avenue

- mercury: exceeded in eight samples sporadically distributed throughout the study area, but the highest concentrations observed were just northwest of the HBHA

- nickel: exceeded in five samples sporadically distributed throughout the study area but the highest concentrations observed in the area between the East Hide Pile and the East Central Hide Pile

- zinc: exceeded in 11 samples sporadically distributed through out the study area but the highest concentration observed in the area of the Regional Transportation Center

- Benzene was the most frequently detected VOC at concentrations exceeding the GW-2 (2,000 µg/L) and GW-3 (7,000 µg/L) standards. In the shallow groundwater, the highest concentrations of benzene were observed in two areas: between the East Central Hide Pile and the South Hide Piles adjacent to Atlantic Avenue (69,000 µg/L); and within a localized area along the eastern edge of the West Hide Pile (4,100 µg/L). In the deeper groundwater, high concentrations of benzene extended from the southern side of Atlantic Avenue to the southern end of the HBHA Pond. In general, the overall benzene plume, extending in both the shallow and deeper groundwater, is located in the vicinity of Atlantic Avenue south to the HBHA Pond. This current location is generally consistent with the findings of previous investigations conducted during the early GSIP investigations and the 1983 RI.

- Although toluene concentrations did not exceed the GW-2 (6,000 µg/L) or GW-3 (50,000 µg/L) standards for samples collected during the Final GSIP Statement of Work and MSGRP, toluene was detected at elevated concentrations with the center of the plume generally located just south of the Atlantic Avenue/Commerce Way intersection.

Elevated concentrations of toluene (up to 2,500 µg/L) were observed in this area. During previous investigations conducted in 1997 by the ISRT as part of the source area investigation, elevated concentrations of toluene were also detected in this same general area with a maximum observed concentration of 19,000 µg/L as well as the intermediate and deeper overburden beneath and immediately south of the BECO right-of-way.

- Trichloroethene (TCE) was observed sporadically in shallow groundwater samples in the vicinity of the BECO right-of way and the HBHA Pond. TCE concentrations did not exceed the GW-2 (300 µg/L) or GW-3 (20,000 µg/L) standards and were generally low (< 6 µg/L) in the shallow groundwater surrounding the HBHA Pond.

- TCE was also detected at higher concentrations (up to 110 µg/L) in the intermediate to deep overburden in another area approximately 0.5 miles south of the Site, generally located south and southwest of Cabot Road, in the vicinity of former Mishawum Lake. TCE degradation by-products (1,1-dichloroethene, cis-1,2-dichlorethene) were also detected, but concentrations did not exceed the GW-2 or GW-3 standards. Based on the available groundwater data, it appears that the source of the TCE along Cabot Road is not related to the Site.

- Although detected naphthalene concentrations did not exceed GW-2 or GW-3 standards, elevated concentrations were observed in shallow groundwater adjacent to and north of the HBHA Pond.

- 1,2-Dichloroethane was detected in well W5-05 at a concentration of 48 µg/L. This concentration exceeds the GW-3 standard of 20 µg/L for this compound.

- Samples collected from varying depths at 10 boring locations along the southern perimeter of the Northern Study Area are considered representative of groundwater quality as it leaves the study area and enters the Wells G&H IWPA and were compared to GW-1 standards. Of the metals detected, only arsenic exceeded its GW-1 standard (50 µg/L). No organic compounds were found to exceed the federal drinking water maximum contaminant levels (MCLs). However, methyl tert-butyl ether in well AF-02 (4,000 µg/L) exceeded the GW-1 standard (70 µg/L). Chloroform was detected in well P1-03 at a concentration (4 µg/L) slightly less than the MCL (5 µg/L). Based on the available groundwater data, it appears that organic compounds present in groundwater along the southern perimeter of the Northern Study Area are not related to the Site.

1.4.3 Summary of Sediment Contaminant Nature and Extent

A total of 429 surface sediment samples (0-6 inches in depth) were collected from river, lake, and wetland locations in all reaches throughout the MSGRP RI Study Area during several GSIP and MSGRP investigations from 1995 through 2004. In addition, sediment samples were also collected from local and regional reference stations from areas not expected to have been impacted by site-related contaminants. All sediment samples were analyzed for metals and some were also analyzed for VOCs, SVOCs, pesticides, and polychlorinated biphenyl compounds (PCBs). Metals concentrations observed in sediments were compared to concentrations found at the reference stations and to regulatory reference criteria, such as the EPA Region 9 PRGs and the Ontario Ministry of the Environment and Energy (OMEE) Severe-Effects Level (SEL) sediment quality guidelines.

- The highest concentrations of metals and the most exceedances of reference criteria were found in the HBHA (Reach 0), the Wells G&H wetlands (Reach 1), and the Cranberry Bog Conservation Area (northern part of Reach 2). The concentrations and frequency of criteria exceedances were generally highest in the HBHA, decreased somewhat in Reaches 1 and 2, decreased further in Reaches 3, 4, and 5, and then increased again in Reach 6 at the Mystic Lakes. The number of metals exceeding reference criteria was highest in Reach 1, followed by Reaches 2 and 0.

- Arsenic exceeded all of the reference criteria cited above, in all reaches. More than 50 percent of the samples exceeded all reference criteria for iron and lead. These exceedances, by reach, are summarized below:

	REACH						
	0	1	2	3	4	5	6
Arsenic	■	■	■	■	■	■	■
Lead		■					■
Iron	■						■

■ Exceeds all reference criteria in >50% of all samples

- Twenty VOCs were detected in study area surface sediment samples. Most compounds were detected infrequently and at low concentrations. Only four compounds (benzene, tetrachloroethene, trichloroethene, and vinyl chloride) exceeded the EPA Region 9 PRGs for residential soil in at least one sample. Benzene exceeded the PRG standard (600 µg/kg) in one sample in Reach 0. In Reach 1, tetrachloroethene exceeded the PRGs in two samples, trichloroethene exceeded the PRGs in five samples, and vinyl chloride exceeded the PRGs in one sample. These four VOCs also exceeded all applicable reference criteria in at least one sample. These exceedances occurred at seven locations in Reaches 0 and 1. No samples from the rest of the study area contained VOCs at concentrations that exceeded all applicable criteria.

- Twenty three SVOCs, primarily polynuclear aromatic hydrocarbons (PAHs), were detected in study area surface sediment samples. The highest concentrations of SVOCs were generally found in Reach 3 and the highest frequencies of exceedance of reference criteria were found in Reaches 0 and 3. Five PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h) anthracene, and indeno(1,2,3-cd)pyrene) exceeded Region 9 PRGs in all study area reaches, and the reference stations. Benzo(b)fluoranthene concentrations exceeded all criteria in at least one sample from every reach. Bis(2-ethylhexyl)phthalate exceeded all criteria at only one location in Reach 0.

1.4.4 Summary of Surface Water Contaminant Nature and Extent

Beginning in May 2001 and ending in October 2002, an extensive 18-month surface water monitoring program was conducted throughout the watershed that included measurements of precipitation, streamflow, suspended sediment, and metals concentrations (dissolved and total), in addition to other physio-chemical parameters at 10 stations located along a 9-mile reach of the Aberjona River. The intensive monitoring period captured monthly baseflow sample data as well as six storm events spanning multiple seasons (spring, summer, and fall).

- Concentrations of metals in surface water sporadically exceeded the National Ambient Water Quality Criteria (NAWQC) at Stations 1-8 during both base flow and storm flow conditions. No exceedances of NAWQC criteria were observed at Station 9 or 10 (Mystic Lakes) at any time. The most frequently detected metals exceeding NAWQC

CCC (chronic criterion) criteria included aluminum, copper, lead, and zinc. Although the concentrations of arsenic were below NAWQC criteria (except one storm event sample collected at Station 4 exceeding the NAWQC CCC), both dissolved and particulate phases of arsenic represent potential impacts to downstream depositional areas. For the majority of the 10 surface water sampling stations, the total arsenic concentrations were highest during storm flow conditions.

- The surface water monitoring data showed that metals transport is highly impacted by total suspended solids (TSS) concentrations. Spikes in metals concentrations are associated with spikes in TSS. Monitoring data collected during baseflow conditions show that arsenic concentrations are higher within the northern portion of the MSGRP RI Study Area in the HBHA. This trend was also observed for the other metals evaluated (chromium, copper, iron, lead, and mercury).

- The highest metals concentrations were most often observed at the outlet of the HBHA (Station 4). Spikes in metals concentrations at this station were associated with spikes in suspended sediment concentrations, indicating that elevated levels of metals at this station are associated with the particulate phase. The total metals concentrations typically decreased downstream of Station 4. During storm events, the highest arsenic concentrations were observed at the outlet of the HBHA Pond (Station 2). A chemocline exists within the HBHA Pond; created by low conductivity water contributed by Halls Brook and high conductivity groundwater contributed from Site-related groundwater. This chemocline effectively, albeit not completely, sequesters arsenic within the pond sediments and lower depths of the HBHA. However, the chemocline becomes unstable during large storm events causing high concentrations in the deep surface water to mix with shallow water, and higher concentrations of arsenic to be released at the outlet.

- The reduction of metal concentrations observed during baseflow conditions between Station 4 and at Station 5 and subsequent downstream stations indicates that deposition is occurring between stations. Sediment samples were collected at significant deposition areas along the HBHA and Aberjona River from the Industri-plex Site to the Mystic Lakes. The distribution of arsenic and other metals along the river shows a clear pattern of metals transport from the northern part of the river and watershed originating at the Industri-plex Site, south to the Mystic Lakes with the greatest area of sediment deposition occurring at the Wells G&H wetland and areas north.

1.5 Fate and Transport of Key Contaminants

Past storage, manufacture, and handling practices of numerous chemicals at the Industri-plex Site has resulted in the release of chemicals to Site soils of VOCs (aromatic hydrocarbons), SVOCs (including phthalates, phenols, and PAHs), and metals. Depending on the combination of Site-related contaminants, geologic and hydrogeologic conditions, and surface features, contaminants released to Site soils have migrated into other environmental media, specifically the underlying groundwater, adjacent surface water bodies, and sediments.

The fate and transport of contaminants evaluated in the MSGRP RI involve complicated and interdependent processes that affect mobilization of contaminants between various media and from reach to reach with the MSGRP RI Study Area. The principal source of contamination within the MSGRP Study Area are the capped soils underlying the Industri-plex Site. These contaminated soils are impacting groundwater, which in turn discharges to the HBHA Pond and wetlands and northern portions of the Aberjona River, subsequently impacting surface water. The surface water flows from the HBHA and Aberjona River combine at Mishawum Road and represents the primary contaminant transport vehicle for downgradient receptors. While the applicable fate and transport processes are generally the same throughout the Study Area, the impacted media and contaminants of concern vary from the northern portions of the Study Area to the lower portions of the Study Area. These general fate and transport processes are depicted in Figure 1-3 and are summarized as follows:

FATE & TRANSPORT MODEL AREA	IMPACTED MEDIA	CONTAMINANTS OF CONCERN
Reach 0 (Industri-plex Site and the HBHA)	Soils, Groundwater, Sediment, Surface water	VOCs, Metals
Reach 1 (38-acre Wells G&H wetland)	Sediment, Surface water, Groundwater	Metals
Reach 2 to Reach 6 (Cranberry Bog Conservation Area to the Mystic Lakes)	Sediment, Surface water	Metals

- The most significant ongoing transport process for metals in soils underlying the Industri-plex Site is leaching to groundwater. Once in groundwater, contaminants continue to migrate via advection, diffusion, and dispersion processes. The contaminants most widely detected in groundwater include arsenic, benzene, toluene, and to a lesser degree lead and zinc. Contaminants are then transported through groundwater flow paths and are predominantly discharged in the northern portions of the HBHA Pond, impacting sediments and surface water.

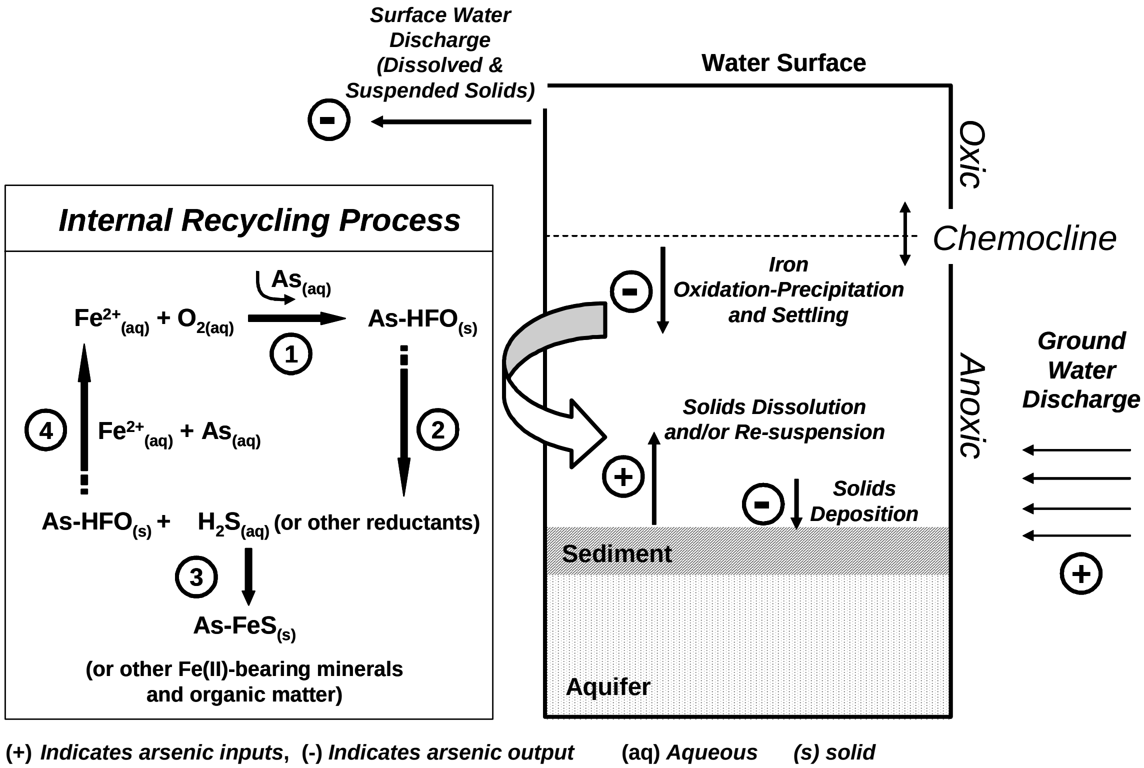
- Portions of groundwater flow at greater depths continue to flow parallel to the main buried valley. As evidenced by downgradient groundwater sample data, the deeper portion of the aquifer does not appear to be a significant pathway for contaminant migration as contaminant concentrations are not being sustained. These contaminants are likely being attenuated by biological and chemical degradation, dispersion, and diffusion processes that are significantly influenced by geochemical conditions.

- Organic compounds in groundwater, such as benzene, discharging into the sediment and deeper portions of the HBHA Pond are generally attenuating to very low concentrations or are not detected in shallow portions of the HBHA Pond surface water. The VOCs in sediments may biodegrade, partition to surface water, or remain bound to the organic matter present in stream sediments. VOCs that enter into surface water can volatilize into the ambient air where they are degraded by photolysis or hydrolysis remain in surface water and undergo degradation processes such as biodegradation, hydrolysis, or reduction-oxidation reactions or become attenuated through dilution, diffusion, and advection. A study conducted by MIT in 2000 concluded that biodegradation at the anoxic/oxic interface was the largest sink for benzene in the HBHA Pond as compared to other fate and transport processes.

- Available data indicate that because of biological activity occurring in VOC-contaminated soils - most probably degradation of aromatic hydrocarbons (benzene and toluene), or natural organic carbon from the wetland deposits as well as the degradation of waste animal hides located in the hide piles and BECO right-of-way - a reducing environment in groundwater has been created at the Industri-plex Site. In turn, metals such as arsenic and iron, are being reduced, rendered more soluble, and therefore much more mobile in groundwater. These actions are evidenced by observed groundwater arsenic levels as well as the presence of arsenic in surface water samples collected in the groundwater discharge zones in the HBHA Pond.

- A fraction of the dissolved arsenic being discharged from groundwater in the HBHA Pond sediments becomes bound to ferric oxides and effectively removed from the water column and becomes part of the sediment load. However, a portion of the dissolved arsenic continues to migrate through the sediments, diffusing further into the water column, whereby the arsenic can either be further sequestered from solution during oxidation and precipitation of ferrous iron at the oxic-anoxic interface or be transported downstream. These reactions are dependent upon a fairly stable chemocline that is present at a depth of 9 to 15 feet, or about mid-way to the bottom of the HBHA Pond. The chemocline is induced by the difference in specific conductance between oxic surface water and anoxic contaminated groundwater, and steady inputs of oxygen, iron, sulfates, and organic carbon from groundwater. The relative position of the chemocline fluctuates throughout the year due to seasonal variations in temperature and surface water flow. Below the chemocline in deep surface water, high concentrations of dissolved arsenic (up to 5,043 µg/L), benzene (up to 2,530 µg/L), and high conductivity were present in the HBHA Pond. Sudden increases in flows, as seen during storm conditions, mix the water column and break down the chemocline, thus allowing more arsenic to be “flushed” downstream. However, the chemocline has been shown to be re-established within a period of less than a month due to the continuous flux of high specific conductance groundwater derived from the Industri-plex Site.

- The basic chemical reactions controlling arsenic distribution and recycling between the sediments and the water column in the HBHA Pond are depicted in the following fate and transport schematic. The schematic on the right represents the overall general processes occurring below the chemocline. The schematic on the left represents the specific chemical reactions taking place between the arsenic, iron, and oxygen. Processes that remove arsenic from the HBHA Pond water column are indicated with minus signs (including discharge to the downgradient wetland and ultimately, the Aberjona River). Maintenance of a relatively stable chemocline is important to the applicability of the reaction scheme in the diagram.



- Once in the surface water column, in either dissolved form or associated with the suspended solid load, arsenic will continue to migrate downstream with the flow of water. Depending on the geochemical and flow conditions, dissolved metals in the water column may absorb to suspended solids, such as fine grained soil particles or other metal complexes, and either precipitate and become part of the sediment bed load, or be transported within the water column as part of the suspended solid load and be deposited at locations downstream.

- As part of the sediment bed load, and depending on the geochemical conditions, metals may dissolve from the sediment particles back into the surface water, whereby the cycle of dissolution and precipitation would continue. This cycling was mostly observed within portions of the HBHA that exhibited significant anoxic/reduced conditions, specifically, within the HBHA Pond. However, whereas wetlands in general typically exhibit reduced conditions or present a significant source of sulfides under oxic conditions, this cycling may be occurring at other portions of the HBHA, but likely at a lesser degree than the HBHA Pond due to its unique geometry, geochemistry, and influx of anoxic groundwater.

- Due to its proximity to the Lower South Pond and wetlands, groundwater along the eastern edge of the West Hide Pile, where another source of benzene was detected, is likely discharging to the surface water of the adjacent pond and wetland areas as evidenced by the absence of benzene in groundwater samples downgradient of the West Hide Pile. Once discharged to the sediments and surface water, the benzene is likely being attenuated by biodegradation, chemical degradation, volatilization, and dispersion as seen in the HBHA Pond.

- Surface water data collected from Halls Brook indicate that during storm events, slightly elevated concentrations of chromium and lead are also flowing into the HBHA Pond. However, only lead exceeded its NAWQC CCC (i.e. chronic) criterion (2.5 µg/L) during both storm event and baseflow conditions. The source for this contamination is likely the New Boston Street Drainway and the East Drainage Ditch based on surface water quality samples collected during construction of the remedy and sediment data collected during this investigation. Historically, Olin Chemical Corporation has been identified as a source of chromium contamination in sediments along the East Drainage Ditch, a small tributary to Halls Brook.

- An evaluation of potential impact of the contaminated river sediments on groundwater in the Wells G&H wetland concluded that the arsenic in the river and wetland sediments and surface water would not adversely affect the development of large-capacity potable water supply wells in the Wells G&H Central Area aquifer. This conclusion was based on historical water quality data from municipal Wells G and H information regarding the hydrologic relationship between the aquifer, the river and the wetlands, geochemical conditions existing in the aquifer; recent water quality data from the sampling of various monitoring wells and surface water stations during site investigations, and known and postulated geochemical behavior of the contaminants and associated metals, notably iron and manganese. These results suggest that arsenic in the river and sediments is unlikely to migrate to drinking water supply well(s) above its current drinking water standard (MCL).

- Based on the surface water data, surface water clearly is the transport mechanism that is facilitating the transport of arsenic (and other metals) through the river system downstream of the Industri-plex Site. This fate and transport mechanism is demonstrated by the baseflow and storm flow surface water sample data collected during the 18-month investigation and is also evidenced by sediment data collected throughout the Aberjona River. Based on these data, the highest concentrations of arsenic are in the northern part of the MSGRP RI Study Area in Reach 0, and steadily decrease as the river flows south through Reach 1-6. Concentrations of arsenic and other metals in surface water at the furthest downstream monitoring stations, located at the Mystic Lakes, show further reductions in metals concentrations, as well as TSS concentrations, during both baseflow and storm flow conditions.

1.6 Human Health and Ecological Risks

Data collected during this investigation were evaluated for potential human health and ecological risks. Separate baseline risk assessments were completed for the Northern Study Area and the Southern Study Area to determine whether contaminated media (surface water, sediment, sediment cores, soil, groundwater, and soil gas) pose risks to human and ecological receptors. The results of the human health and ecological risk assessments have been combined into a comprehensive risk evaluation for the Industri-plex Site and the entire Aberjona River. The comprehensive risk assessment results are summarized in the following sections.

1.6.1 Human Health Risks

For the purposes of the human health risk assessments, the Northern and Southern Study Areas were divided into stations, defined as areas of recreational use (wading or swimming) along the Aberjona River, Mystic Lakes, HBHA, and associated wetland/floodplain areas at which human exposures to multiple environmental media (soil, sediment, and surface water) may occur. Additional areas containing residual soil contaminants (the former Mishawum Lake bed) were also evaluated. Northern Study Area groundwater was comprehensively evaluated for potential direct (industrial use) and indirect (subsurface migration to indoor air) contaminant exposures.

Prior to completion of the human health risk assessments, EPA completed an arsenic bioavailability study to assist in the quantification of sediment risks and hazards, which determined that site-specific arsenic is absorbed less efficiently from sediment than from a water medium. Based on this study, the relative bioavailability estimate was used to quantify sediment ingestion risks and hazards. In addition, site-specific chromium VI (hexavalent chromium) data for sediments in the Northern and Southern Study Area and soils in the Northern Study Area were collected and used in the risk assessments to more accurately characterize sediment and soil risks and hazards at the study areas. The 95% Upper Confidence Limits (UCLs) were calculated using USEPA's software program ProUCL version 3.0, and used as exposure point concentrations (EPCs) whenever possible.

The potential non-carcinogenic hazards and carcinogenic risks for the central tendency (CT) and reasonable maximum exposure (RME) cases were estimated. Exposure assumptions used in the risk assessment are provided in Appendix A, Tables 2-1 through 2-6. An overall summary of locations and media where estimated carcinogenic risks and non-carcinogenic hazards exceed the USEPA target cancer risk range of 10^{-6} to 10^{-4} and/or a target hazard index of 1 for non-carcinogenic effects is presented in Table 1-1 and Figures 1-4 and 1-5. The evaluation of current and potential future surface water, fish, and soil gas exposures did not result in the estimation of carcinogenic risks and non-carcinogenic hazards above regulatory guidelines and are not discussed further. Cumulative receptor risks and hazards, summed across all applicable media, are provided in the Northern and Southern Study Areas baseline human health risk assessments. The areas with human health risks exceeding EPA's target risk range or target hazard index are discussed below, by medium.

1.6.1.1 Sediment

Recreational exposures evaluated included incidental ingestion of and direct dermal contact with accessible sediments. Accessible sediments were defined as sediments present in areas of mild to moderate vegetation, of generally shallow (less than two feet) and slow moving surface water, with gradual banks, and/or less than 30 feet from shore. Recreational receptors (young children, teenagers, and/or adults) were selected for evaluation at individual stations after consideration of current and reasonable potential future land use (residential, park land, or commercial). Based on the City of Woburn's February 2005 draft redevelopment plan, future reuse plans are not anticipated for the interior wetlands represented by Station NT-1 (nature trail with wetland board walk) and NT-2 (nature trail with wetland pier). Hence, sediment exposure pathways for NT-1 and NT-2 are currently considered incomplete, and have not been included in the listing of locations exceeding risk management guidelines below. If necessary, these decisions will be further reviewed upon finalization of the City's redevelopment plan.

Figure 1-4 shows the locations of the sediment stations associated with current and future risks and hazards in excess of regulatory guidelines.

- For the current scenario, risks and hazards above risk management guidelines were estimated for sediment exposure at Station WH, located near well H in the Wells G&H 38-acre wetland north of Salem Street in Woburn, and Station CB-03, located on the western-central side of the former cranberry bog immediately south of Salem Street. In Summer 2004, these areas were posted with warning signs discouraging contact with sediments in these two areas.

- For the future scenario, potential risks and hazards above risk management guidelines were estimated at Stations 13/TT-27, WH, NT-3, and CB-03. All stations are located within the Wells G&H 38-acre wetland except for Station CB-03, the sample in the former cranberry bog. Station NT-3 is an area within potential future land use scenarios developed by the City of Woburn for the construction of a nature trail within the Wells G&H wetland. Station NT-3 and WH generally represent the same exposure area. Station 13/TT-27 is located on the western side of the Wells G&H 38-acre wetland.

- The risk exceedances were due primarily to the presence of arsenic in sediment. For Stations 13/TT-27, WH, and CB-03, areas of significantly elevated arsenic concentrations were localized in nature. Benzo(a)pyrene was also a minor risk contributor at Stations 13/TT-27 and WH. The risk associated with benzo(a)pyrene and the concentrations of benzo(a)pyrene present at these stations fall within the range of estimated risks and detected concentrations at the reference stations.

1.6.1.2 Sediment Cores

Sediment cores were evaluated for a potential future dredging scenario which assumed that workers would contact contaminated sediments up to 4 feet in depth during excavation/dredging for flood mitigation and control construction projects. Worker exposures evaluated included incidental ingestion of and direct dermal contact with sediments. Figure 1-4 shows the sediment core locations associated with future risks and hazards in excess of regulatory guidelines.

- For the future scenario, hazards above risk management guidelines were estimated at sediment core locations SC02, located in the HBHA wetland, and SC05, SC06, and SC08, located within the Wells G&H 38-acre wetland. The risk exceedances were due primarily to the presence of arsenic in sediment.

1.6.1.3 Soil

Recreational exposures evaluated included incidental ingestion of and direct dermal contact with floodplain soils. Recreational receptors (young children, teenagers, and/or adults) were selected for evaluation at individual stations after consideration of current and potential future land use (residential, park land, or commercial). In addition, residual soil contaminants within the former Mishawum Lake bed were evaluated for potential exposures to current and/or future day care children, groundskeepers, and construction workers. Figure 1-4 shows the soil locations associated with future risks and hazards in excess of regulatory guidelines.

- For the future scenario, risks and hazards above risk management criteria were estimated for future day care children exposed to surface (i.e., SO-13, SO-14 and SO-16) and subsurface soils (i.e., SO-13, SO-11, SO-3, and SO-14) within the former Mishawum Lake bed area due primarily to arsenic.

- Non-carcinogenic hazards above risk management criteria were estimated for future construction workers exposed to subsurface soils (i.e., SO-13, SO-11, SO-3, and SO-14) within the former Mishawum Lake bed area due primarily to arsenic.

1.6.1.4 Groundwater

Specific industrial groundwater use evaluated included process water use (incidental ingestion, dermal contact, and inhalation exposures) and the use of groundwater in a warm water car wash (inhalation exposures). Because groundwater throughout the study area is relatively shallow, future construction workers may also be exposed to groundwater contaminants during excavations down to the water table. Figure 1-5 shows the monitoring well locations associated with future risks and hazards in excess of regulatory guidelines. Risks and hazards in excess of regulatory guidelines were estimated for groundwater used as process water, used in a warm water car wash, and for worker-related exposures to shallow groundwater.

- The primary risk contributor for process water use and for construction worker-related exposures is arsenic. The elevated arsenic concentrations associated with risks and hazards above risk management criteria are found within the boundaries of the Industri-plex Site and the HBHA Pond area.

- Benzene, trichloroethene, and naphthalene were also identified as primary risk contributors for process water use and the use of groundwater in a warm water car wash within the boundaries of the Industri-plex Site and the HBHA Pond area. Trichloroethene in groundwater was also identified as a primary risk contributor for the Cabot Road area. Based on available groundwater data, it appears that the source of trichloroethene along Cabot Road is not related to the Site.

- Additional minor risk contributors for process water and warm water car wash use include: 1,2-dichloroethane, chloroform, and methyl tert-butyl ether. 1,2-Dichloroethane was also localized within the Industri-plex Site. Chloroform and methyl tert-butyl ether were only found along the southern perimeter of the Northern Study Area. Based on available groundwater data, chloroform and methyl tert-butyl ether do not appear to be related to the Site.

- Arsenic contaminated groundwater discharges primarily to the HBHA Pond. It should be noted that the migration of arsenic-contaminated surface water from the HBHA in the Northern Study Area to depositional areas in the Southern Study Area (i.e., the Wells G&H 38-acre wetland and the former cranberry bog) contribute to the human health risks and hazards above risk management guidelines observed at sediment stations 13/TT-27, WH, NT-3, and CB-03 in the Southern Study Area.

1.6.1.5 Uncertainty

The following summarizes the major sources of uncertainty in the risk assessments:

- In cases where there is high degree of variability between the data points for a contaminant, an exposure point concentration (EPC) may be uncertain. For example, the sediment EPC for arsenic at sediment core location SC02 is uncertain due to one elevated arsenic detect (1,600 mg/kg in the 0- to 1- foot depth interval) compared to the remainder of the data set. This uncertainty is also applicable to SO soils due to sampling location SO-13 (2,680 mg/kg in the 8-foot interval), sediments at Station 13/TT-27 due to sampling locations SD-13-01-FW and SD-13-02-FW (4,210 mg/kg and 2,480 mg/kg), sediments at Station WH due to sampling location SD-12-01-ME (3,230 mg/kg), and sediments at Station CB-03 due to sampling location CB-03-11 (1,410 mg/kg). This uncertainty may result in either an overestimate or underestimate of risk and hazard.

- Even though low-flow sampling techniques were used to collect Northern Study Area groundwater samples, a number of monitoring wells could not be stabilized prior to the collection of groundwater samples. These samples may have contained elevated levels of suspended particulate materials, resulting in an overestimate of the bioavailable contaminant levels in the samples. Risk estimates based on groundwater samples containing elevated levels of suspended solids may overestimate risk and hazard.

- Future air EPCs for the industrial and commercial groundwater use scenarios were generated from groundwater data through the use of volatilization and dispersion modeling. Parameter values used in these models were selected to represent reasonable maximum exposures that may occur in the future should groundwater be used as process water or for use in a warm water car wash. The risk and hazard associated with future groundwater use may be less than estimated should groundwater uses that result in a lower degree of worker exposures be considered (e.g., use of groundwater for cooling in a closed system).

1.6.2 Ecological Risks

The baseline ecological risk assessments used effects-based screening criteria to identify contaminants of potential concern (COPCs) in each medium. Receptor species were selected for exposure evaluation to represent various components of the food chain in the river/wetland ecosystem, and included: muskrat, green heron, mallard, short-tailed shrew, benthic invertebrates, and several species of warm water fish. In addition, in the Northern Study Area, a piscivorous mammal, the river otter, was also evaluated.

The risks identified for each receptor were reviewed with consideration of the level of the risk to the population or community, the uncertainty associated with the analysis, and the amount and quality of the affected resource. The results were interpreted further within the context of the magnitude of the effect, the uncertainty of the estimates, and the ecological significance of the effect. Overall summaries of estimated risks are presented for each receptor species or community in Table 1-2.

Each endpoint has associated with it a magnitude of risk and a degree of uncertainty. The magnitude of risk incorporates both the degree to which the endpoint was exceeded and also the proportion of the habitat affected. Since the endpoints were population-based, a reasonable probability of risk was determined to be present only when a risk was present throughout the majority of the organism's habitat. The ecological significance related to each receptor/endpoint was evaluated in terms of factors defined by EPA. An evaluation of these factors is used to clarify if risks associated with contamination are present at levels that represent unacceptable ecological risk. Each of the six categories evaluated in Table 1 were used to support a conclusion about the ecological significance of each endpoint where risk was identified. The magnitude of the potential risk was further considered when evaluating the significance of each factor.

Based on the analysis of the seven selected indicators/endpoints, the only area of unacceptable ecological risk is in the HBHA Pond, where the potential risk to aquatic receptors is due to benzene and arsenic in the deeper water. The potential risk to the benthic invertebrate community is due to inorganic COPCs, especially arsenic. In addition, evidence suggests that there is high exposure to inorganic COPCs, especially arsenic, for semi-aquatic mammals, bottom feeding fish, and small forage fish in several other areas in the MSGRP RI Study Area. However, in general, the resulting level of ecological risk for these receptors is low. The magnitude of these risks and the uncertainty associated with the ecological effects for each receptor is discussed below.

1.6.2.1 Ecological Risks Due to Surface Water

Surface water screening indicated a possible risk to aquatic life from exposure to benzene and arsenic in the HBHA Pond. Exposure is mainly to aquatic invertebrates in the deep water at the sediment-water interface. Downgradient of HBHA Pond, the surface water concentrations of dissolved arsenic were below NAWQC and were well below those expected to cause effects on aquatic life, including invertebrates, and fish.

1.6.2.2 Ecological Risks Due to Sediment

The effect of sediment contaminants on sediment-dwelling benthic invertebrates was the subject of extensive analysis, including toxicity testing, invertebrate tissue analyses, and benthic invertebrate community studies. An evaluation of the benthic invertebrate measurement endpoints indicates that there were potential impacts from inorganic contaminants on invertebrate communities within the study area. Data were used to evaluate the relationship of sediment contaminant concentrations, benthic invertebrate toxicity testing results, and benthic community composition data.

- There is evidence of severe toxicity to benthic organisms at the HBHA Pond. Some evidence of invertebrate toxicity was also observed indicating potential effects from exposure to sediments at stations downstream of the HBHA Pond in the HBHA Wetland sediments and in reaches 1 and 2 of the Southern Study Area. The toxicity testing results were highly correlated to sediment arsenic concentrations, particularly when the effect of high iron concentrations was taken into account.

- Although severe impairment of communities was not observed in the Southern Study Area, a reduction in diversity and an increase in dominance of oligochaetes and chironomids was observed in stations with higher arsenic concentrations.

- Based on multivariate analysis of community composition, the strongest factors affecting the invertebrate community were the acid volatile sulfide (AVS) content of the sediment, the depth of the sampling location, the dissolved oxygen in the overlying water, and the habitat characteristics (flow) of the location from which the sample was collected. These factors are considered environmental variables that are not associated with chemical contamination. When these environmental variables are segregated from the overall community composition effects, the results show a portion of the community structure is strongly correlated to the sediment arsenic:iron ratio. Stations with high arsenic concentrations, but with high iron as well, have lower toxicity due to the effect of iron to bind arsenic in less toxic forms. The availability and toxicity of arsenic in the

HBHA Pond is unique due to the strongly reducing conditions in the water. The discharge of dissolved arsenic at the sediment-water interface, at concentrations well above NAWQC values, support the conclusions that the absence of invertebrates is related to contamination in the sediments of the pond.

- The levels of contaminants observed outside of the HBHA Pond correspond to detectable but small changes in community composition correlated to contaminant concentrations in the sediment, particularly with arsenic:iron ratios. The analysis indicates that the benthic community shows some shifts in community composition which is associated with the bioavailable fraction of arsenic in the sediment (represented by the arsenic:iron ratio). The community analyses also support the conclusions that the community structure at the two deep stations in the HBHA Pond are uniquely impaired and dissimilar to other study area and reference stations.

The summary of risk (Table 1-2) indicates a difference in the magnitude of the risk to benthic invertebrates between the HBHA Pond and the remainder of the combined study area. In the HBHA Pond, there is a high risk and confidence, based on several supporting lines of evidence, that there is severe toxicity and impairment of benthic communities. In the downgradient areas (HBHA Wetlands and the Southern Study Area), the evidence indicates a low magnitude of toxicity, although there was a high correlation of effects with distribution of site contaminants (primarily arsenic). Since benthic invertebrates provide important functions in aquatic ecosystems, the impact on the benthic community in the HBHA Pond, with severe toxicity and impairment of benthic communities, represents a significant ecological effect. Due to the magnitude of the adverse effect on this receptor community, the impact on the benthic community in the HBHA Pond represents an unacceptable ecological risk.

1.6.2.3 Ecological Risks Due to Soil

Risks from exposure to soil-related contaminants were evaluated first by screening soil concentrations against soil screening benchmarks. As a second step, effects on terrestrial receptors exposed to soil contaminants through ingestion of biota exposed to soils was addressed in the food chain models using short-tailed shrew as the small mammal receptor.

1.6.2.4 Ecological Risks to Fish

The potential effects of contaminant exposure on fish populations were evaluated through analysis of fish tissue COPC concentrations in both the Northern and Southern Study Areas. In addition, population studies were conducted in the Northern Study Area in order to document the fish community structure at two study area ponds (HBHA Pond and HBHA Wetland Pond No. 3) as compared to two reference ponds.

- The population data from the Northern Study Area indicated impairment of fisheries; however, the relative influence of poor quality habitat conditions could not be distinguished from impacts associated with toxicity from contaminants. The tissue data provided evidence of potential ecological effects in the Northern Study Area and negligible effects in the Southern Study Area; although population data are inconclusive about the role of toxicity in impairing fish populations in the Northern Study Area ponds. The risks to fish were possibly underestimated based on the inability to discern any impacts from the exposure to toxic substances from impacts associated with the limited and poor overall habitat.

- The risks to fish populations is located in the Northern Study Area ponds and associated with the high exposure to arsenic. The area of highest exposure and potential impacts is in the HBHA Pond and the HBHA Wetland Pond No. 3, which also represents an area of relatively low quality aquatic habitat. The value of the potential resource at risk is relatively high, as the affected receptors included populations of several species of bottom feeding and small foraging fish. The magnitude of the risk is low, with uncertainty (Table 1-2) related to the lack of ability to discern impacts associated with contamination from the population studies. Although this endpoint represents a potential impact of relatively high ecological significance, the measured magnitude of the risk is low, and associated with uncertainty. Hence, the overall impact on fish populations is not considered an unacceptable ecological risk.

1.6.2.5 Ecological Risks to Wildlife

Estimates of dietary exposures for wildlife were quantified for each of the selected receptor species. Dietary exposure models were used to estimate exposure of each receptor species to each of the COPCs identified in the screening of sediment, surface water, and soil data (as applicable) from the study areas.

- Based on the dietary modeling, there were negligible risks to green heron from exposure to COPCs in both of the study areas. In addition, there were negligible risks to river otter from exposure to COPCs through dietary exposure in the Northern Study Area. The majority of the diet for both green heron and river otter was based on consumption of fish. Since the concentrations of COPCs in fish tissue were generally lower in the Southern Study Area, risks to otter in these reaches are also negligible (Table 1-2).

- Food chain modeling based on site-specific data indicated negligible risk to mallard duck from exposure to COPCs in the Northern Study Area. For mallard, chromium, lead, and mercury posed low risk in the Southern Study Area, mainly within the Wells G&H 38-acre wetland, resulting from high sediment concentrations of these metals in Reaches 1 and 2. The likelihood that high concentrations of sediment metals in limited areas of the 38-acre wetland will have serious population effects on a species with wide foraging ranges, like mallards, is low. Although habitat of the 38-acre wetland is considered to be of relatively high quality and local ecological significance, the low probability of impacts on the receptors result in low ecological significance of the effects on waterfowl (Table 1-2). Hence, the impact on the mallard population is not considered an unacceptable ecological risk.

- Based on the muskrat models, there is potential risk to muskrat from ingestion of arsenic. These risks have been evaluated in the context of the limitations of the data and the models. Within this context the risk to muskrat exceeds levels potentially associated with harm (growth or reproduction), but the uncertainty associated with these estimates is high. The relatively low magnitude of the risk estimates (HQ values less than 10) and the high uncertainty associated with the models leads to a conclusion of low probability of significant population effects on muskrat in the study areas. Based on the data collected, the risk assessment does not provide sufficient evidence to conclude that arsenic contamination in the study areas is causing an adverse effect on muskrat populations that is of sufficient magnitude, severity, and extent that the population will not be maintained in an acceptable state. Hence, the impact on the muskrat population is not considered an unacceptable ecological risk.

- Arsenic was identified as posing a potential effect on shrew in both the Northern and Southern Study Areas. The relatively low magnitude of the risk estimates and the high uncertainty associated with the models leads to a conclusion of low probability of significant population effects on short-tailed shrew and other small terrestrial mammals in the study area. The available habitat for small terrestrial mammals such as short-tailed shrew is limited to the borders of the wetland. Although the habitat for small mammals may be locally important, the magnitude of the potential effects is low (with high uncertainty), leading to a conclusion of no significant ecological effects related to contaminant exposures to small mammal populations (Table 1-2). Hence, the impact on the shrew populations is not considered an unacceptable ecological risk.

1.6.2.6 Ecological Risk Conclusions

Based upon the evaluation conducted under this Baseline Ecological Risk Assessment Summary for the combined study areas, significant ecological risks are present in the HBHA Pond within the Reach 0 of the Northern Study Area immediately downstream of the current Industri-plex Superfund Site boundaries. These significant risks were primarily associated with metals contamination, particularly arsenic, in the sediments and their toxicological effects on the benthic invertebrate community.

Risks to aquatic organisms are also associated with high observed concentrations of benzene and dissolved arsenic in the deep water of the HBHA Pond. Dissolved arsenic concentrations were measured significantly above NAWQC values for aquatic life. These risks are consistent with the observed impairment of benthic invertebrates in the deep water of the HBHA Pond. These significant risks are considered unacceptable ecological risks to the HBHA Pond.

Risks to receptors downgradient of HBHA Pond are low (Figure 1-6). These include low risks to benthic invertebrates and herbivorous mammals, associated with high concentrations of sediment arsenic. These low risks are not considered unacceptable ecological risks to ecological communities in the HBHA Wetlands, Wells G&H 38-acre wetland, and Former Cranberry Bog.

1.6.3 Summary of Human Health and Ecological Risks

Chemicals have been detected in some areas of the MSGRP RI Study Area that have been shown to present human health risk and hazards above EPA risk management guidelines and unacceptable ecological risks. At a minimum, cleanup alternatives should be developed in the Feasibility Study to address the areas and major risk contributors summarized in the following table:

HUMAN HEALTH RISK			
RISK AREA	**SCENARIO/ RECEPTOR**	**IMPACTED MEDIA**	**MAJOR CONTAMINANT CONTRIBUTING TO RISK**
Industri-plex Site (Reach 0)	Future Construction Worker	Groundwater	(NC) - Arsenic
Industri-plex Site / HBHA Pond Area (Reach 0)	Future Industrial Worker	Groundwater, Indoor air	(NC) - Benzene, naphthalene, arsenic (C)- Trichloroethene
Former Mishawum Lake & South of Cabot Road Area (Reach 0)	Future Industrial Worker	Groundwater, Indoor air	(C)- Trichloroethene
Industri-plex Site / HBHA Pond Area (Reach 0)	Future Car Wash Worker	Indoor air	(C)- Trichloroethene (NC) - Benzene, naphthalene
Former Mishawum Lake & South of Cabot Road Area (Reach 0)	Future Car Wash Worker	Indoor air	(C)- Trichloroethene
Wells G&H Wetland (Reach 1); and Former Cranberry Bog (upper Reach 2)	Current/ Future Recreational Exposure	Sediment	(C) – Arsenic (NC) – Arsenic
HBHA (Reach 0); and Wells G&H Wetland (Reach 1)	Future Dredger/ Construction Worker	Sediment	(NC) – Arsenic
Former Mishawum Lake Area (Reach 0)	Future Day Care Child (surface soil)	Soil	(C) - Arsenic
	Future Day Care Child (subsurface soil)	Soil	(C) – Arsenic
	Future Const. Worker (subsurface soil)	Soil	(NC) - Arsenic
ECOLOGICAL RISK			
HBHA Pond	Benthic Invertebrate Communities	Sediment , Deep surface water	Arsenic and Benzene

(NC) – Non-carcinogenic Hazard (C) – Carcinogenic Risk

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Remedial alternatives are developed by assembling combinations of technologies and the media to which they would be applied into an appropriate range of alternatives that address site contamination. This section presents the preliminary phase of the remedial alternatives development process. The process consists of the following steps:

- Development of RAOs that is protective of human health and the environment and which specify the contaminants and media of concern, exposure pathways, and PRGs that permit a range of treatment and containment alternatives.
- Development of general response actions for each medium of interest that define measures that may be taken singly or in combination to satisfy the RAOs.
- Identification of the volumes or areas of media to which the general response actions might be applied.
- Identification and screening the technologies applicable to each general response action.

Section 2.1 presents a preliminary listing of ARARs and other guidance to be considered in the development of RAOs. Section 2.2 presents the RAOs for each contaminated medium at the Site and areas identified in the MSGRP Study Area. Section 2.3 presents the general response actions that may be implemented to achieve the RAOs for each medium and identifies the volumes and areas of media to which the general response actions may be applied, and Section 2.4 presents the screening of technologies and process options.

2.1 Applicable or Relevant and Appropriate Requirements (ARARs)

Section 300.430(f) of the NCP requires that on-site remedial actions at CERCLA sites must meet ARARs under federal or state environmental or facility siting laws unless there are grounds for invoking a waiver. Other federal and state advisories, criteria, or guidance, as appropriate (to be considered [TBCs]), should be considered in formulating the remedial action.

ARARs are promulgated, enforceable federal and state environmental or public health requirements. There are two categories of requirements: "applicable" and "relevant and appropriate". Under CERCLA, a regulation may either be considered, "applicable" or "relevant and appropriate," but not both. These categories are defined below:

Applicable Requirements – Section 300.5 of the NCP defines applicable requirements as "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site".

Relevant and Appropriate Requirements – Section 300.5 of the NCP defines relevant and appropriate requirements as "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site."

To be considered (TBCs) guidelines are non-promulgated criteria, advisories, and guidance issued by the federal or state governments. Along with ARARs, TBCs may be used to develop the interim action limits necessary to protect human health and the environment.

ARARs requirements under CERCLA pertain to on-site activities only. Off-site activities relating to hazardous waste disposal are required to meet all applicable laws including, but not limited to: Department of Transportation regulations governing the marking and labeling of hazardous materials shipments (49 CFR 192), shipping requirements (49 CFR 173), and transport of hazardous materials by motor vehicles (49 CFR 173 and 49 CFR 177); the RCRA regulations governing transporter activities and treatment, storage, and disposal facilities (40 CFR 261-264), land disposal restrictions (40 CFR 268), off-site response actions (40 CFR 300.440); and CERCLA 121(d)(3).

The Occupational Safety and Health Administration (OSHA) regulations are not ARARs, but apply to both on- and off-site activities. These include regulations governing performance of activities at hazardous waste sites (29 CFR 1910.120), general construction guidelines (29 CFR 1926), and occupational exposure to asbestos (29 CFR 1910.1001).

ARARs and TCBs are divided into three categories: chemical-specific, location-specific, and action-specific. In Sections 2.1.1 through 2.1.3, these categories are briefly described and potential ARARs and TBCs for the Site are identified.

2.1.1 Chemical-Specific ARARs

Chemical-specific ARARs are typically health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the determination of numerical values that establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment. In general, chemical-specific requirements are set for a single chemical or a closely related group of chemicals. These requirements do not consider the mixture of chemicals. Potential chemical-specific ARARs are summarized in Table 2-1.

2.1.1.1 Chemical-Specific ARARs for Soil and Sediment

Currently, there are no promulgated federal or state chemical-specific ARARs appropriate for the MSGRP Study Area that would provide limits for the concentrations of chemicals in soil or sediment. As such, chemical-specific threshold concentration values (preliminary remediation goals) that will be used to guide soil and sediment remedial actions are derived using TBC guidance and site-specific risk-based criteria. Also refer to Section 2.1.4 below for more information regarding TBCs.

2.1.1.2 Chemical-Specific ARARs for Surface Water

There are federal chemical-specific ARARs for surface water. The U.S. EPA has published an updated compilation of its national recommended water quality criteria for 158 pollutants, developed pursuant to Section 304(a) of the Clean Water Act (CWA or the Act). Section 304(a)(1) of the Act requires EPA to develop and publish, and from time to time revise, criteria for water quality accurately reflecting the latest scientific knowledge. Water quality criteria developed under Section 304(a) are based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects.

Section 304(a) criteria do not reflect consideration of economic impacts or the technological feasibility of meeting the chemical concentrations in ambient water (EPA, 2002). These criteria are referred to as the NAWQC.

Similarly, the MADEP has adopted the Massachusetts Surface Water Quality Standards (314 CMR 4.00). These standards designate the most sensitive uses for which the various waters of the Commonwealth shall be enhanced, maintained, or protected. This standard also contains regulations necessary to achieve the designated uses and maintain existing water quality including, where appropriate, the prohibition of discharges. Where recommended limits are not available, site-specific limits shall be developed.

2.1.1.3 Chemical-Specific ARARs for Groundwater

Since groundwater at this Site is not used for a public drinking water supply (refer to Section 1.3.1), there are no chemical-specific ARARs for groundwater for this Site. As such, chemical-specific threshold concentration values (preliminary remediation goals) that will be used to guide soil and sediment remedial actions are derived using TBC guidance and site-specific risk-based criteria. Also refer to Section 2.1.4 below for more information regarding TBCs.

Relevant and Appropriate federal and state ARARs pertaining to groundwater discharges and potential impacts to surface water however, are identified. These include the Clean Water Act and the Massachusetts Surface Water Quality Standards ARARs, which are discussed above in Section 2.1.1.2.

2.1.2 Location-Specific ARARs

Location-specific ARARs are restrictions placed on the concentrations of hazardous substances, or the conduct of activities solely because they are in specific areas. The general types of location-specific ARARs that may be applied to remedial actions at the MSGRP Study Area are briefly described below and summarized in Table 2-2.

Several federal and state ARARs regulate activities that may be conducted in wetlands or floodplains. The Wetlands Executive Order (E.O. 11990) and the Floodplains Executive Order (E.O. 11988), incorporated into 40 CFR Part 6, Appendix A, require that wetlands and floodplains be protected and preserved, and that adverse impacts be minimized. State wetland protection regulations (310 CMR 10.00) and state waterways regulations (310 CMR 9.00) restrict activities that adversely affect wetlands and waterways, respectively.

Additional federal location-specific ARARs include the Fish and Wildlife Coordination Act, which requires that any federal agency proposing to modify a wetland or body of water must consult with the U.S. Fish and Wildlife Service; and the Endangered Species Act, which would need to be considered for any proposed on-site actions.

2.1.3 Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are generally focused on actions taken to remediate, handle, treat, transport, or dispose of hazardous wastes. These action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative must be implemented. The general types of action-specific ARARs that may be applied to remedial actions at the MSGRP Study Area are briefly described below and summarized in Table 2-3.

The types of action-specific requirements that may be considered will depend on the nature of the remedial actions selected. Federal and state National Permit Discharge Elimination System (NPDES) permit programs may be used to govern discharges to surface waters associated with the implementation of certain construction or remedial processes. A number of RCRA regulations govern emissions from equipment, tanks, and containers that are used as part of a remedial action.

2.1.4 To Be Considered Criteria

As stated previously, TBCs are non-promulgated federal and state advisories or guidance that are not legally binding and do not have the status of being applicable or relevant and appropriate. However, if there are no specific regulatory requirements for a chemical or site condition, or if ARARs are not deemed sufficiently protective, then guidance or advisory criteria should be identified and used to ensure the protection of human health and the environment.

TBCs that will be considered for the MSGRP FS include risk assessment advisories and guidance values (such as cancer slope factors, reference doses) that will be used to derive preliminary remediation goals for soil, sediment, and groundwater. For example, the MADEP has established soil categories based upon the potential exposures which may result from the presence of oil or hazardous material in commonly contaminated media. These categories are established based on a site-specific risk/exposure analysis. The MADEP soil standard for arsenic in soil is 30 ppm. However, this standard is relevant, but not appropriate at this Site. EPA has proposed a PRG of 50 ppm for arsenic in soil, based upon its Human Health Risk Assessment. MADEP has concurred not only with the findings of the risk assessment, but also with the EPA-proposed cleanup standard and agrees that it is sufficiently protective of human health in these circumstances. Because the only risks found were to future construction workers performing subsurface work or to children in a daycare setting, institutional controls will prevent exposures to soils posing a risk to human health by imposing limits on excavation and limiting the future use of the property.

In addition, UCLs in soil and groundwater are concentrations of oil and/or hazardous material which, if exceeded under certain conditions, indicate the potential for significant risk of harm to public welfare and the environment under future conditions. If UCLs are exceeded, the MCP imposes specific requirements for addressing the risk posed by the contamination which exceeds UCLs. The UCL for arsenic in soil is 300 ppm. EPA and MADEP have concluded that UCLs have not been exceeded in the soils at the former Lake Mishawum lakebed.

2.2 Development of Remedial Action Objectives (RAOs)

Remedial action objectives consist of medium-specific goals for protecting human health and the environment. The RAOs specify the media and contaminants of concern, exposure routes and receptors, and preliminary remediation goals for each exposure route. By specifying both exposure pathways and preliminary remediation goals, the RAOs permit the development of a range of alternatives that may achieve protection by reducing exposure to contaminated media.

The media of concern for the MSGRP Study Area were identified based on the results of site-specific baseline human health and ecological risk assessments performed for the site and study area, as well as the fate and transport evaluation presented in the MSGRP RI (TtNUS, 2005). The baseline risk assessments identified excess cancer risks or non-cancer hazards associated with human exposure to site soils, sediment, and groundwater; and ecological risks associated with exposures to site sediment and surface water. Fate and transport evaluations indicated that the flow of Site groundwater is transporting contaminants into surface water and sediments, and that storm water flow conditions are mobilizing contaminated surface water and sediments into the water column, enabling their transport and deposition to downstream areas.

Groundwater risks and hazards were evaluated for three areas: (1) the Industri-plex site/HBHA Pond area; (2) Cabot Road area; and (3) Mishawum Road area. Trichloroethene, detected in the intermediate to deep overburden south and southwest of Cabot Road, was identified as a groundwater risk contributor. Methyl tert-butyl ether and chloroform, detected in samples collected from varying depths along the southern perimeter of the Northern Study Area (i.e., the Mishawum Road area), were also identified as groundwater risk contributors. However, based on the available groundwater data, it appears that the sources of trichloroethene, methyl tert-butyl ether, and chloroform in the Cabot and Mishawum Road areas are not related to the Site. Therefore, only the risk contributors identified for the Industri-plex Site/HBHA Pond area have been further considered in the development of RAOs.

This section documents the formulation of RAOs for the MSGRP Feasibility Study. RAOs were developed based on the results of the RI, the baseline human health and ecological risk assessments, and the ARARs identification. For each contaminated medium of concern, the three major components of the RAO development process are discussed: identification of the contaminants of concern (COCs), identification of the exposure routes and receptors, and development of an acceptable contaminant level for each exposure route (i.e., a preliminary remediation goal). The RAOs for each medium that are presented in the following subsections include specific references to each of these components. The RAOs, by medium, are summarized in Table 2-4.

When proposing medium-specific PRGs, human health and ecological risk-based PRGs, risk assessment uncertainties, background concentrations, consistency with previous cleanup goals, and other site-specific considerations (e.g., ARARs) are evaluated to select the proposed PRG. Human health risk-based PRGs are developed and presented in Appendix A. The human health risk-based PRGs provided in Table 2-5a correspond to target cancer risk levels of 10^{-6}, 10^{-5}, and 10^{-4} and a target noncancer hazard quotient (HQ) of 1. A human health risk-based PRG may be selected corresponding to any of the target risk/hazard levels identified, so long as the cumulative cancer risk and target organ non-cancer hazard for a receptor meet regulatory guidelines (cumulative incremental lifetime cancer risk (ILCR) of 10^{-6} to 10^{-4} and target organ non-cancer hazard index (HI)] of 1). The goal is to select a risk-based PRG that affords the maximum degree of protection; but also considers and allows for the inclusion other site-specific information (e.g., background concentrations). Therefore, regional and site-specific background concentrations are also provided in Table 2-5a, as applicable, to be considered in the selection of a proposed PRG for naturally-occurring or anthropogenic compounds, such as arsenic and benzo(a)pyrene. Overall, the most conservative receptors have been considered in selecting the proposed PRGs.

2.2.1 Development of RAOs and PRGs for Soil

This section presents the development of RAOs for soil. Once soil COCs, exposure routes, and receptors are identified based on the results of the baseline risk assessments, the PRGs are established for soil.

2.2.1.1 Soil Contaminants of Concern, Exposure Routes, and Receptors

No unacceptable ecological risks were identified for soil. Tables 1-1 through 1-3 in Appendix A summarize the Reasonable Maximum Exposure (RME) human health risk and hazard estimates that contribute to a soil ILCR greater than 10^{-4} and/or a target non-cancer HI greater than 1 and the pathways associated with these estimates as summarized in the baseline human health risk assessment. Arsenic was identified as the only soil COC in the baseline human health risk assessment. The baseline risk assessment identified excess cancer risks and non-cancer hazards from direct contact with surface and subsurface soils by a future day care child, and non-cancer hazards from direct contact with subsurface soils by a future construction worker. The direct contact exposure routes evaluated include incidental ingestion and dermal contact. The locations for these risks and hazards are soil sample locations within the former Mishawum Lake bed (Figure 2-1).

2.2.1.2 Soil Remedial Action Objectives and Preliminary Remediation Goals

To address the human health risks and hazards that were identified for contaminated soil at the site, the following RAOs were developed for the protection of human health:

- Prevent exposures associated with an incremental lifetime cancer risk greater than 10^{-6} to 10^{-4} and or a HI greater than 1 by meeting the associated PRGs for the following scenarios:
  - Ingestion and dermal contact of arsenic by children at a future day care center for surface and subsurface soil within the former Mishawum Lake bed area and
  - Ingestion and dermal contact of arsenic by a future excavation worker for subsurface soil within the former Mishawum Lake bed area.

Risk-based soil PRGs for the protection of human health from exposure to arsenic in soil are developed based on information provided in Appendix A for the day care child and construction worker receptors. Tables 2-1 through 2-3 in Appendix A provide the equations and exposure parameters used to calculate the risk-based PRGs for these receptors. The risk-based PRGs for the two receptors, summarized in Table 2-5a, correspond to target cancer risk levels of 10^{-6}, 10^{-5}, and 10^{-4} and a target non-cancer hazard quotient (HQ) of 1. A regional background soil concentration for arsenic (20 mg/kg) has also been provided in Table 2-5a.

Because only one COC was identified for soil, a risk-based PRG for the most sensitive receptor corresponding to, but not exceeding, an HQ of 1 may be selected so long as the cancer risk level corresponding to this value is less than 10^{-4}. The day care child is identified as the most sensitive receptor. It should be noted that uncertainties were discussed in the risk assessment related to the arsenic cancer slope factor and the assumptions applied to the exposure scenarios evaluated. The uncertainties were noted as generally biasing the risk and hazard estimates toward overestimation.

Thirty-four soil samples were collected from the former Mishawum Lake bed area. The arsenic soil concentrations in all 34 samples exceed the risk-based PRG of 1 mg/kg corresponding to a cancer risk of 10^{-6} for the day care child. Twenty-eight of the 34 samples demonstrated arsenic levels in excess of the risk-based PRG of 10 mg/kg corresponding to a cancer risk of 10^{-5} for the day care child. Both of these risk-based PRGs correspond to soil concentrations less than the regional background value of 20 mg/kg. Note that 19 of 34 samples demonstrated arsenic levels in excess of the 20 mg/kg regional background value. Fourteen and 11 of the 34 samples demonstrated arsenic levels in excess of the 40 mg/kg (risk-based PRG of 10^{-6} for the construction worker) or 50 mg/kg value (risk-based PRG for HQ of 1 for the day care child), respectively.

The proposed PRG for arsenic in soil for the protection of human health will be to attain a concentration of 50 mg/kg, the non-cancer risk-based PRG for the day care child (HQ of 1) which corresponds to a cancer risk of approximately 3×10^{-5} for the day care child and 2×10^{-6} for the construction worker (see Table 2-5b). The proposed PRG (50 mg/kg) represents cumulative receptor risks and hazards that are within risk management guidelines, considers background concentrations of this naturally-occurring COC, and also considers the uncertainties associated with the risk and hazard estimates that overall, tend to be biased toward overestimation.

2.2.2 Development of RAOs and PRGs for Groundwater

This section presents the development of RAOs and PRGs for groundwater. Direct ecological exposures to groundwater were not assumed to occur. Therefore, groundwater COCs, exposure routes, and receptors are identified based on the results of the baseline human health risk assessment.

2.2.2.1 Groundwater Contaminants of Concern, Exposure Routes, and Receptors

Tables 1-3, 1-14 and 1-15 in Appendix A summarize the RME human health risk and hazard estimates that contribute to the groundwater ILCRs greater than 10^{-4} and/or target non-cancer HIs greater than 1 and the pathways associated with these estimates as summarized in the baseline human health risk assessment. Based on the results of the baseline human health risk assessment for the Northern Study Area, arsenic, benzene, trichloroethene (TCE), 1,2-dichloroethane, and naphthalene were identified as contaminants that result in an ILCR > 10^{-4} or HI > 1. These contaminants will be the COCs for groundwater for the MSGRP Feasibility Study. Figure 2-2 shows the locations of groundwater samples where these COCs exceeded an ILCR

$> 10^{-4}$ or HI > 1. Only the risk contributors identified for the Industri-plex site/HBHA Pond area have been further considered in the development of RAOs and PRGs.

The human health risk assessment for the Northern Study Area identified excess cancer risks and non-cancer hazards associated with groundwater use by a future industrial worker (i.e., process water use) and future car wash worker; and non-cancer hazards from direct contact with groundwater by a future construction worker. The exposure routes evaluated include incidental ingestion and dermal contact with groundwater and/or inhalation of volatile compounds released from groundwater. The exposure point location for these groundwater risks and hazards is the Industri-plex Site/HBHA Pond area.

2.2.2.2 Statement of Groundwater RAOs

The findings of the human health risk assessments were used to develop the RAOs for groundwater. As previously stated in Section 1.3.1, the MADEP "Groundwater Use and Value Determination" for the Industri-plex site (MADEP, 1997) concluded that the aquifer in the Northern Study Area was of low use and value and classified the aquifer as a non-potential drinking water source area because of its concentrated industrial development. Therefore, a residential drinking water scenario was not evaluated for the Northern Study Area.

The ecological risk assessments did not identify groundwater as a medium that posed risk to ecological receptors because direct contact with groundwater was not assumed in the baseline ecological risk assessment. However, an RAO for the protection of the environment was developed to address discharges of contaminated groundwater to the HBHA Pond, which were identified as a source of sediment and deep surface water contamination in the pond, and downstream HBHA Wetlands, Aberjona River and adjacent wetlands.

Protection of Human Health

The groundwater RAOs for the protection of human health were developed based on the evaluation of risk and hazard associated with the future groundwater exposure scenarios described above. The groundwater RAOs for the Industri-plex Site/HBHA Pond area for the protection of human health are:

- Prevent exposures associated with an ILCR greater than 10^{-6} to 10^{-4} and/or HI greater than 1 by meeting the associated PRGs for the following scenarios:

  - Ingestion, dermal contact, and/or vapor inhalation of arsenic, benzene, naphthalene, trichloroethene, and 1,2-dichloroethane by an industrial worker using groundwater as process water,
  - Ingestion and dermal contact of arsenic by an excavation worker, and
  - Vapor inhalation of benzene, naphthalene, trichloroethene, and 1,2-dichloroethane by a car wash worker using groundwater in the job.

Protection of the Environment

The groundwater RAO for protection of the environment addresses groundwater discharges to the HBHA Pond:

- Protect benthic invertebrates and aquatic life from exposure to levels of benzene and arsenic indicative of impairment due to groundwater discharges or provide alternative habitat (HBHA Pond only in the event that the HBHA Pond is used as a component of the remedy).

2.2.2.3 Groundwater Preliminary Remediation Goals

Risk-based groundwater PRGs for the protection of human health are developed based on information provided in Appendix A for the use of groundwater as process water, in a car wash, and for direct contact by a construction worker. Tables 2-5 and 2-6 in Appendix A provide the equations and exposure parameters used to calculate the risk-based PRGs for these receptors. Tables 5-1 through 5-3 in Appendix A provide additional exposure and modeling information for the dermal and inhalation components of the risk-based PRGs. The risk-based PRGs for the three receptors, summarized in Table 2-5a, correspond to target cancer risk levels of 10^{-6}, 10^{-5}, and 10^{-4} and a target non-cancer HQ of 1. In addition, a regional background groundwater concentration for arsenic (5.5 ug/L) has been provided.

For benzene, the risk-based PRG corresponding to a cancer risk of 1×10^{-5} (4 µg/L) for the use of groundwater in a car wash, the most conservative exposure scenario, is selected as the proposed PRG for benzene. This value corresponds to a noncarcinogenic HQ of 0.1. For 1,2-dichloroethane, a proposed PRG of 2 µg/L is selected. This value corresponds to a cancer risk of approximately 1 x 10^{-5} and a noncarcinogenic HQ of 0.3 for the car wash worker scenario, the most conservative scenario for this compound. A value of 1 µg/L is selected as the proposed PRG for TCE. This value is consistent with a Practical Quantitation Limit (PQL) for TCE and corresponds to a cancer risk of 3 x 10^{-5} and a non-carcinogenic HQ of 0.02 for the car wash worker scenario. For naphthalene, 5 µg/L is selected as the proposed PRG which corresponds to a HQ of 1 for the process water scenario, the most sensitive scenario for this compound. It should be noted that uncertainties were discussed in the risk assessment related to the air modeling assumptions applied to the process water and car wash worker scenarios. The uncertainties were noted as generally biasing the risk and hazard estimates toward overestimation.

The risk-based PRG for arsenic corresponding to an ILCR of 10^{-6} for the process water scenario (4 µg/L) is less than the regional background groundwater arsenic concentration of 5.5 µg/L and less than upgradient reference concentrations of arsenic which ranged up to 10.5 µg/L. The risk-based PRG for an ILCR of 10^{-5} (40 µg/L) is marginally greater than the upper range of the upgradient reference concentrations. As previously noted, uncertainties were discussed in the risk assessment related to the arsenic cancer slope factor and the assumptions applied to the exposure scenarios evaluated. The uncertainties were noted as generally biasing the risk and hazard estimates toward overestimation. In addition, the Industri-plex OU-1 ROD allowed soils with up to 300 mg/kg arsenic to remain on-site. These soils serve as a potential source of contamination to groundwater, making cleanup of the aquifer to concentrations approaching background concentrations difficult. Therefore, the proposed arsenic PRG of 150 µg/L is selected which corresponds to an ILCR of 4 x 10^{-5} and a noncarcinogenic HQ of 0.3. The proposed PRG (150 ug/L) also represents the fresh water chronic NAWQC for arsenic which protects aquatic life.

The proposed PRGs for the groundwater COCs represent cumulative receptor risks and hazards that are within risk management guidelines, consider background concentrations of naturally-occurring COCs and PQLs, factor in the presence of residual arsenic-containing soils at the site, and also consider the uncertainties associated with the risk and hazards estimates that overall, tend to be biased toward overestimation.

COC-specific PRGs for site groundwater, developed to protect human health, are provided in Table 2-5b. PRGs for arsenic, benzene, naphthalene, TCE, and 1,2-dichloroethane that were detected in the Industri-plex Site/HBHA Pond area are based on risk-based determinations of concentrations of each contaminant that would provide a level of risk that is within the acceptable range established for the Site (ILCR < 10^{-4} and HI < 1), as noted on Table 2-5b.

2.2.3 Development of RAOs and PRGs for Sediment

The development of RAOs for sediment is considerably more complex than for the other media that are addressed in this FS. Areas of human health and ecological risk were identified for sediment at the Site and within the MSGRP Study Area, and these findings provide the basis for the development of sediment RAOs. The evaluation of the fate and transport of contaminants is also considered for the development of sediment RAOs, since extensive research has suggested that contaminated sediment continues to migrate further downstream with the flow of surface water. This migration potentially creates additional human health or ecological risks as new contaminants are deposited in the downstream portions of the MSGRP Study Area (refer Section 1.0). The following sections describe the process that was used to develop the RAOs for sediment.

2.2.3.1 Sediment Contaminants of Concern, Exposure Routes, and Receptors

Based on the results of the human health and ecological risk assessments, arsenic is the primary COC for sediment, contributing to risk at each location where unacceptable risks were identified. Benzo(a)pyrene was also identified as a sediment COC in the baseline human health risk assessment at certain sampling locations. The following paragraphs describe the human health, ecological, and fate and transport considerations that were assumed in order to develop RAOs for sediment that will address the COCs, exposure routes, and receptors identified in the baseline risk assessments.

Human Health Considerations

Tables 1-4 through 1-13 in Appendix A summarize the RME human health risk and hazard estimates that contribute to sediment ILCRs greater than 10^{-4} and/or target non-cancer HIs greater than 1 and the pathways associated with these estimates as summarized in the baseline human health risk assessment. The baseline human health risk assessments for the Northern and Southern Study Areas identified several areas of potential risk and hazard associated with recreational exposures to contamination in accessible sediment. Accessible sediments were defined as sediments present in areas of mild to moderate vegetation, of generally shallow (i.e., less than 2 feet) and slow moving surface water, with gradual banks, and/or less than 30 feet from shore. The accessible sampling stations that exhibited human health risks and hazards in excess of regulatory criteria were located within the Wells G&H wetland and the Cranberry Bog Conservation Area. The baseline human health risk assessments also identified areas of potential risk and hazard associated with sediment cores collected to evaluate potential future risks and hazards to dredging workers. These areas are described in more detail in the following paragraphs.

Cancer risks and/or non-cancer hazards in excess of regulatory criteria were identified for potential exposures to accessible sediment by current and future recreational users. The sampling stations where these risks and hazards were identified were concentrated in the accessible portions of the Wells G&H wetland (13/TT-27, WH, NT-3), with one station located at the Cranberry Bog Conservation Area (CB-03). The direct contact exposure routes evaluated include incidental ingestion and direct dermal contact.

Non-cancer hazards in excess of regulatory criteria were also identified in two general locations for future exposures to dredging workers. The exposure point locations for these hazards are sediment core sample location SC02, located in the eastern side of the Halls Brook Holding Area, approximately 1,200 feet south of the HBHA Pond, and sediment core sample locations SC05, SC06, and SC08 within the Wells G&H wetland. The direct contact exposure routes evaluated include incidental ingestion and direct dermal contact.

Ecological Risk Considerations

The baseline ecological risk assessments for the Northern and Southern Study Areas identified the HBHA Pond as the only area where unacceptable ecological risks are present. The sampling stations that exhibited unacceptable ecological risks were associated with sediment samples from both deep and shallow areas within the HBHA Pond. Toxicity of sediments in HBHA Pond was associated with high concentrations of arsenic. Direct exposure of HBHA Pond sediments from both deep (MC-05 and MC-07) and shallow (MC-06) stations resulted in toxicity of benthic invertebrates. These stations also exhibited highly impaired benthic invertebrate communities, and elevated concentrations of metals in invertebrate tissue.

Contaminant Fate and Transport Considerations

As discussed in Section 1.0, the fate and transport evaluation that was performed as part of the MSGRP RI identified sediment re-suspension, arsenic dissolution, and surface water flow as a major transport mechanism that has allowed, and continues to allow, the migration of contaminants from the HBHA Pond to the downstream areas of the river. Surface water sampling results collected during base flow and storm flow conditions suggest that increased surface water flow due to storm events increase the effects of these transport mechanisms. While surface water contaminant concentrations have not been observed to exceed NAWQC criterium for arsenic outside of the HBHA Pond, measurements of arsenic flux observed during base flow and storm flow events suggest that significant quantities of arsenic are migrating downstream with the flow of surface water during storm events (TtNUS, 2005a).

Also, although they do not present a risk to human health or the environment, sediments within a section of the New Boston Street Drainway located in the Boston Edison right-of-way may be impacted by groundwater discharges. This is the location where the highest groundwater concentration of arsenic (24,000 µg/L) was observed. Concentrations of arsenic in sediment samples collected in this area were greater (up to 384 mg/kg) than those observed in upgradient sample locations (as low as 16.3 mg/kg) Based on surface water data collected during the 18-month investigation, some of these contaminated sediments are mobilized during storm events and eventually discharge into the HBHA Pond, contributing to the contaminated sediment load within the pond, impacting ecological receptors in the HBHA Pond, and potentially migrate to downstream depositional areas.

Similarly, although they do not present a risk to human health, soils adjacent to the southern border of the Boston Edison right-of-way and adjacent to the HBHA Pond exhibited elevated concentrations of arsenic. These contaminated soils could erode into the HBHA Pond, contributing to the contaminated sediment load, potentially impacting ecological receptors in the HBHA Pond, and potentially migrate to downstream depositional areas.

2.2.3.2 Statement of RAOs for Sediment

RAO development for sediment was performed separately for each of the following geographical areas where sediment risks were identified: HBHA Pond and Halls Brook Holding Area, Wells G&H wetland, and Cranberry Bog Conservation Area. This approach enabled the development of RAOs that address the specific exposure routes and receptors that apply to each area so that the range of remedial alternatives that is evaluated is appropriate to reduce risks in that area. This section presents the RAOs for sediment that were developed to address each of these areas.

Protection of Human Health

The following sediment RAOs were developed for the protection of human health:

- Prevent exposures to sediment associated with an ILCR greater than 10^{-6} to 10^{-4} and/or HI greater than 1 by meeting the associated PRGs for the following scenarios:

    - Ingestion and dermal contact of accessible arsenic and benzo(a)pyrene for current and future recreational land use at the Wells G&H wetland stations WH, NT-3, and 13/TT-27,
    - Ingestion and dermal contact of accessible arsenic for current and future recreational land use at the Cranberry Bog Conservation Area station CB-03, and
    - Ingestion and dermal contact of arsenic for future dredging workers at sediment core locations SC02 (HBHA wetland) and SC05, SC06, and SC08 (Wells G&H 38-acre wetland).

- Minimize to the extent practicable, the migration of soluble and particulate arsenic during storm events to downstream depositional areas.

Protection of the Environment

The following RAO was developed to address ecological risks in the HBHA Pond due to contamination in sediment: Protect benthic invertebrates from toxicological impacts indicative of impairment as compared to reference habitats or provide alternate habitat in the event that the

HBHA Pond is used as a component of the remedy. Meet ARAR for the protection of aquatic life (Table 2-4).

2.2.3.3 Sediment Preliminary Remediation Goals

Protection of Human Health

Risk-based sediment PRGs for the protection of human health from exposure to COCs in sediment are developed based on information provided in Appendix A for the recreational user and dredging worker receptors. Tables 2-3 and 2-4 in Appendix A provide the equations and exposure parameters used to calculate the risk-based PRGs for the recreational user and dredging worker, respectively. Arsenic was identified as a sediment COC for both accessible sediments and sediment cores. Benzo(a)pyrene was also identified as a COC for accessible sediments within the Wells G&H wetland (stations WH and 13/TT-27). The risk-based PRGs for the two receptors, summarized in Table 2-5a, correspond to target cancer risk levels of 10^{-6}, 10^{-5}, and 10^{-4} and a target non-cancer HQ of 1. Site-specific background sediment concentrations for arsenic and benzo(a)pyrene have also been provided in Table 2-5a.

Because two COCs (arsenic and benzo(a)pyrene) were identified for accessible sediment, risk-based PRGs for the recreational user should not exceed a cumulative HI of 1 and a cumulative cancer risk level of 10^{-4}. However, because only one COC (arsenic) was identified for sediment cores, a risk-based PRG for the dredging worker corresponding to, but not exceeding, an HQ of 1 may be selected so long as the cancer risk level corresponding to this value is less than 10^{-4}. It should be noted that uncertainties were discussed in the risk assessment related to the cancer slope factors for the COCs and the assumptions applied to the exposure scenarios evaluated. The uncertainties were noted as generally biasing the risk and hazard estimates toward overestimation.

For benzo(a)pyrene, site-specific background data indicate the range of background concentrations fall between 0.13 mg/kg and 5.5 mg/kg with a mean background concentration of 1.3 mg/kg and a 95% UCL background concentration of 4.9 mg/kg (see Table 2-5a). The risk-based PRGs of 0.4 mg/kg and 4 mg/kg, corresponding to 10^{-6} and 10^{-5} cancer risks, respectively, are both less than the 95% UCL background concentration. Selection of the 95% UCL background benzo(a)pyrene concentration of 4.9 mg/kg as the PRG is protective of approximately a 10^{-5} cancer risk for the recreational user within the Wells G&H wetland (accessible sediment stations WH and 13/TT-27). Benzo(a)pyrene was not identified as a risk contributor within the Cranberry Bog Conservation area or for station NT-3 within the Wells G&H wetland. The proposed PRG (4.9 mg/kg) represents cumulative receptor risks and hazards that are within risk management guidelines, considers background concentrations of this anthropogenic COC, and also considers the uncertainties associated with the risk estimates that overall, tend to be biased toward overestimation.

Two different PRGs are developed for arsenic in accessible sediments because the two exposure areas (Wells G&H wetland and the Cranberry Bog Conservation Area) differ in the potential frequency of contact with accessible sediments based on the degree of residential development in each area. For arsenic, risk-based PRGs for a 10^{-6} cancer risk are less than the 95% UCL background concentration for arsenic of 33 mg/kg (see Table 2-5a). Risk-based PRGs based on a cancer risk of 10^{-5} (40 mg/kg for CB-03 and 50 mg/kg for WH, NT-3, and 13/TT-27) correspond to concentrations only slightly above the background range of concentrations (3.8 mg/kg to 40.6 mg/kg; Table 2-5a). The risk-based PRGs associated with an HQ of 1 (230 mg/kg for CB-03 and 300 mg/kg for WH, NT-3, and 13/TT-27) correspond to approximately a 6 x 10^{-5} cancer risk. Therefore, the proposed PRGs for arsenic in accessible sediment for the protection of human health will be to attain concentrations of 230 mg/kg (for the Cranberry Bog Conservation Area) or 300 mg/kg (for the Wells G&H 38-acre wetland area), the non-cancer risk-based PRGs for the recreational user (HQ of 1) which corresponds to a cancer risk of approximately 6 x 10^{-5} for this receptor. The proposed PRGs (230 mg/kg and 300 mg/kg) for the two exposure areas represent cumulative receptor risks and hazards that are within risk management guidelines, consider background concentrations of this naturally-occurring COC, and also consider the uncertainties associated with the risk and hazard estimates that overall, tend to be biased toward overestimation.

For dredging worker exposure to arsenic in sediment cores, a risk-based PRG for a 10^{-6} cancer risk (30 mg/kg) is less than the 95% UCL background concentrations for arsenic of 33 mg/kg. A risk-based PRG corresponding to a cancer risk of 10^{-5} (300 mg/kg) is associated with concentrations above the background range of concentrations (3.8 mg/kg to 40.6 mg/kg). The proposed PRG for arsenic in sediment cores for the protection of human health will be to attain a concentration of 300 mg/kg, the 10^{-5} cancer risk-based PRGs for the dredging worker, which is associated with a HQ of less than 1. It should be noted that the proposed sediment core PRG is consistent with the arsenic soil cleanup level stated in the Industri-plex OU-1 ROD of 300 mg/kg. The proposed PRG (300 mg/kg) represents cumulative receptor risks and hazards that are within risk management guidelines, considers background concentrations of this naturally-occurring COC, and also considers the uncertainties associated with the risk and hazard estimates that overall, tend to be biased toward overestimation.

The proposed PRGs for sediment are based on site-specific risk-based determinations of the concentration thresholds that would provide a level of risk consistent with the target risk values that have been established for the FS. These proposed PRGs are presented, by contaminant, on Table 2-5b.

Protection of the Environment

Risks to ecological receptors from exposure to sediment in HBHA Pond were identified in the ecological risk assessment. The evidence for benthic invertebrate measurement endpoints indicated that there are impacts from metals contaminants on invertebrate communities within the study area. The comparison of sediment concentrations to effects-based benchmarks indicate that there are potential effects on benthic communities from metals, especially arsenic, cadmium, chromium, copper, lead, mercury, and zinc. The toxicity testing supports the conclusion that there are adverse ecological effects on the composition of the benthic community associated with high concentrations of metals in the sediment. The toxicity and community impairment is highly correlated to sediment arsenic concentrations, particularly when the effect of high iron concentrations is taken into account.

There is evidence of severe toxicity to benthic organisms at deep stations in HBHA Pond. The data also present strong evidence of toxicity to invertebrates at station MC-06 in the shallow area of HBHA Pond. Community composition data indicate highly impaired benthic community with low abundance and diversity in the sediments of HBHA Pond in deep water. In the shallow area of HBHA Pond, the community indices show evidence of impairment with limited number of taxa, low diversity, and high dominance of pollution-tolerant oligochaetes.

The benthic invertebrate tissue data also add to the weight of evidence for the effects of arsenic, as the concentration of arsenic in invertebrate tissue exceed ecological effects levels and is greatly elevated at station MC-06. In general, elevated concentrations of metals in invertebrate tissue correspond to locations with high toxicity, but show less association with concentrations of the same metals in downstream sediments. These results indicate that the toxicity and impairment to benthic invertebrates in HBHA Pond are likely related to the forms of metals in the sediment having higher toxicity and/or bioavailability than the same metals present in sediments downstream.

Based on these site-specific data, the PRG for sediments was based on concentrations of arsenic in sediment that would provide a level of risk that is within the acceptable range. There were a limited number of toxicity test samples from the HBHA Pond; the lowest concentration of sediment arsenic associated with significant effects (survival and growth reduction, two species) in toxicity test was 273 mg/kg. This concentration of sediment arsenic represented the lowest-observed-effects-concentration (LOEC) for arsenic. There were no toxicity tests in HBHA Pond that resulted in a no-adverse-effects-level (NOEC), consequently a NOEC could not be established from data collected in HBHA Pond.

Since the habitat and geochemistry conditions in areas downstream of the HBHA Pond in the HBHA Wetlands and in areas to the south were not similar to those observed in the HBHA Pond, results from these analyses were not used to establish PRGs in the Pond. Consequently, the LOEC of 273 mg/kg is selected as the PRG based on the available sediment toxicity testing data from the HBHA Pond. Preventing exposure to sediments at arsenic levels above this arsenic concentration is assumed to protect benthic invertebrates from toxicological impacts (significant reduction in growth or survival as compared to reference locations). However, there is uncertainty associated with the selection of this PRG based on a LOEC rather than an NOEC. It is assumed that the selected PRG will be protective and meet the RAO of protecting benthic invertebrates from toxicological impacts indicative of impairment as compared to reference habitats. However, it is assumed that upon the completion of the remedy sediment toxicity testing will be conducted to demonstrate that exposure to sediments causing toxicity to benthic invertebrates has been attained. The lack of toxicological effects is defined as demonstrating that the sediments have no significant toxicity to invertebrates in laboratory tests for either Chironomus tentans or Hyalella azteca for survival or growth in long-term (20 or 28-day) tests. Significant toxicity is defined as a statistically significant difference from a reference sample and greater than 20 percent reduction in survival or growth. The latter criterion is the percent reduction that is generally considered to represent an unacceptable reduction of growth or survival as compared to reference toxicity tests.

2.2.4 Development of RAOs and PRGs for Surface Water

Human health and ecological exposures to surface water were evaluated for current and future recreational users and ecological receptors in the Northern and Southern Study Areas. Surface water contaminants of potential concern (COPCs) were selected for the baseline human health and ecological risk assessments based on a comparison of surface water sample analytical results to Region 9 PRGs for tap water and NAWQC. COPCs were developed for both base flow and storm events, based on samples collected during each condition.

2.2.4.1 Surface Water Contaminants of Concern, Exposure Routes, and Receptors

The baseline risk assessments did not identify unacceptable risks to human or ecological receptors from surface water at either the Northern or Southern Study Areas under base flow or storm event conditions, with the exception of exceedances of water quality benchmarks for aquatic life in the deep water of HBHA Pond. Despite the fact that direct contact with surface water did not constitute a risk to human or ecological receptors, it is evident that surface water plays an integral part in the transport of contaminated sediment to downstream receptors. As discussed in Section 1.0, the evaluation of fate and transport of contaminants throughout the MSGRP Study Area that was performed for the RI identified sediment re-suspension and dissolution of arsenic absorbed to sediments as a major transport mechanism for contaminants in surface water. Re-suspension of sediment typically occurs during storm events that create increased surface water volume, which in turn causes an increase in surface water turbidity. Suspended solids, originating from contaminated sediments at the bottom of the surface water body, are then transported downstream with the flow of surface water and ultimately deposited into the bottom of the surface water body at a location further downstream. In addition, geochemical conditions in the sediment and deeper portions of the HBHA Pond may cause the dissolution of arsenic from sediments into the water column. These fate and transport processes are discussed more thoroughly in Section 1.0 and in the MSGRP RI.

2.2.4.2 Statement of Surface Water RAOs

RAO development for surface water was for the deeper portions of the HBHA Pond where elevated concentrations of arsenic and benzene were observed and where evidence of toxicological impairment was observed for sediment invertebrates. The following RAO was developed to address ecological risks in the HBHA Pond due to contamination in surface water:

- Protect aquatic life from arsenic and benzene above levels indicative of impairment or provide alternate habitat in the event that the HBHA Pond is used as a component of the remedy. Meet ARARs for the protection of aquatic life (Table 2-4).

In addition, the close interaction between contaminated sediments and surface water necessitates an evaluation of the impacts that remedial actions will have on surface water contaminant levels and contaminant migration patterns. Contaminant migration through sediment re-suspension, sediment dissolution, surface water flow, and downstream deposition is suspected to have transported arsenic contamination to downstream areas of the river, where potential low-level risks to benthic communities from exposure to contaminated sediment have been identified. For this reason, the evaluation of remedial alternatives will consider the ability of the remedial action to decrease, to the extent practicable, the re-suspension of sediment into surface waters and the transport of contamination through the flow of surface water. The identification and screening of remedial technologies for sediment will include measures that are designed to decrease or eliminate continued resuspension of contaminated sediment and/or migration of contaminated suspended solids through the flow of surface water.

2.2.4.3 Surface Water Preliminary Remediation Goals

COC-specific PRGs for deep surface water of HBHA Pond were developed to protect aquatic life and to comply with ARARs. Table 2-5 presents the candidate list of PRG numerical values identified for surface water. PRGs for arsenic and benzene that were detected in the Northern Study Area are based on available surface water benchmarks protective of aquatic life.

For arsenic, the NAWQC (150 ug/L) is an ARAR, and was selected as the PRG for dissolved arsenic. This value is the concentration for chronic exposure established to be protective of aquatic life. For benzene there is no NAWQC value established. There are insufficient site-specific data to establish a PRG for benzene. Consequently the TIER II benchmark (46 ug/L; EPA, 1996), which is calculated using a method similar to the method used to establish NAWQC values, but with lower confidence due to limited available aquatic effects data, is selected as the PRG for the protection of aquatic life.

High concentration of dissolved arsenic in the deep water of HBHA Pond is associated with the discharge of groundwater and the related unique geochemical conditions which allow the release of dissolved arsenic into the hypolimnion (deep water) of HBHA Pond. The identification and screening of remedial technologies for surface water will include measures that are designed to reduce or eliminate continued discharge of arsenic and benzene in groundwater to the deep water of HBHA Pond and will address the related geochemical conditions, such as low dissolved oxygen and strong reducing conditions, that develop in the pond.

2.3 General Response Actions

General response actions are media-specific measures that may be taken to satisfy the RAOs for the Site. General response actions may include containment, extraction, treatment, disposal, and institutional actions, or a combination of these measures. The general response actions developed for MSGRP Study Area soil, sediment, surface water, and groundwater are presented in the following sections, along with an initial identification of the areas or volumes of contaminated media to which the general response actions might be applied.

2.3.1 General Response Actions and Volume of Contaminated Soil

Table 2-6 presents a summary of the RAOs and general response actions identified for soil, along with an initial identification of the general remedial technology types and process options that correspond to each general response action. Several general response actions were identified to provide a wide range of possible options for satisfying the RAOs for site soil, including the following:

- No Action (required by CERCLA)
- Limited Action
- Containment
- Removal
- Treatment
- Disposal

The technologies and process options that are identified on Table 2-7 will be screened and evaluated in Section 2.4. The following paragraphs provide a description of the areas to which these general response actions will be applied to mitigate the risks that have been identified.

Areas with soil contaminants exceeding the PRG are generally concentrated in the area of the former Mishawum Lake bed. See Figures 2-3a and 2-3b for surface and subsurface soil locations, respectively, and areas requiring remediation (707,598 square feet for surface soils, and 1,618,820 square feet for sub-surface soils). These areas are estimated based on widely spaced data and the approximate boundary of the former Mishawum Lake. Areas that were sampled included soil locations in planter beds or locations off-pavement. Most of these areas have been commercially developed and are mostly covered with asphalt pavement or covered by building foundations and slabs. Since the former lake bed deposits may have consisted of peats and other organic deposits, it is assumed that these lake bed deposits would have been removed and replaced with structural fill prior to constructing critical structural features under a building (e.g. foundation).

Also, since the two scenarios evaluated for soil exposure included both a day-care child and a construction worker being exposed to subsurface soil, the most stringent PRG (50 mg/kg – arsenic) was used to calculate the impacted soil volume. The assumed soil depth that will require remedial action is 0 to 3 feet for surface soil and 3 to 15 feet for subsurface soil.

2.3.2 General Response Actions and Volume of Contaminated Groundwater

Table 2-6 presents a summary of the RAOs and general response actions identified for groundwater, along with an initial identification of the general remedial technology types and process options that correspond to each general response action. Several general response actions were identified to provide a wide range of possible options for satisfying the RAOs for groundwater. These general response actions include the following:

- No Action (required by CERCLA)
- Limited Action
- Hydraulic Containment
- Extraction
- Ex-Situ Treatment

- Discharge
- In-Situ Treatment

The technologies and process options that are identified on Table 2-8 will be screened and evaluated in Section 2.4.

As stated in Section 1.4.1, contaminated soils at the Industri-plex Site are the principal source of site-wide groundwater contamination, in particular heavy metals, including arsenic. The 1986 ROD for soils at the Industri-plex Site evaluated several remedial options including complete removal of all contaminated soils. However, it was determined at that time to be impractical due to the significant costs (greater than $245 million) and technically infeasible due to the significant volumes and technical challenges posed by the existing site conditions. Since the 1986 ROD was signed, additional studies have been conducted to support the MSGRP RI and this FS. These studies have determined that significant deposits of organic materials located onsite, originating from both natural sources (peat deposits) and anthropogenic sources (animal hide waste deposits) are creating geochemical conditions that favor the dissolution and mobilization of arsenic from the soils and wastes. In order to address the soils as a source of groundwater contamination, an alternative would be required to not only remove the sources of gross contamination, but also address the site-wide chemically reducing conditions that support arsenic migration by removing or controlling the organic deposits located throughout the site. For the same reasons considered when developing the 1986 ROD, such an alternative is considered technically infeasible and impractical. Consequently, remedial alternatives for groundwater focus on the management of contaminant migration and the prevention of exposure rather than removal.

Impacted groundwater located at the Industri-plex Site and HBHA Pond areas are where human health risks and hazards were determined and is the focus of the groundwater RAOs for this FS. This area contains a groundwater contamination plume consisting of sub-areas where arsenic, benzene, trichloroethene, 1,2-dichloroethane, and naphthalene concentrations exceeded risk-based threshold concentrations for a mixture of exposure scenarios including a construction worker, worker being exposed to process water, and a car wash worker. Whereas different PRGs have been developed for each scenario, the most stringent for each contaminant will be used in calculating the area of groundwater that requires remediation. The areas of these plumes are depicted in Figure 2-4. The evaluation of remedial alternatives for groundwater will focus on the elimination of potential human health risks associated with the groundwater contamination areas described above.

2.3.3 General Response Actions and Volume of Contaminated Sediment

Table 2-6 presents a summary of the RAOs and general response actions identified for sediment, along with an initial identification of the general remedial technology types and process options that correspond to each general response action. Since groundwater discharges to the HBHA Pond and is impacting sediments, the general response actions selected are dependent upon the general response actions selected for groundwater. For example, selecting a sediment treatment or sediment removal option would only be applicable if the groundwater was being treated, otherwise the sediments would become re-contaminated by groundwater discharges. These dependent relationships are further evaluated and discussed in Sections 3.0 and 4.0. The general response actions that were evaluated for the remediation of sediment include the following:

- No Action (required by CERCLA)
- Limited Action
- Containment
- Removal
- Treatment
- Disposal

The technology types and process options identified on Table 2-9 will be the candidate technologies for the preliminary screening that is described in Section 3.0.

As described in Section 2.2.3.1, the baseline human health risk assessment identified several isolated areas where the concentration of arsenic in sediment presented risk to current and future site users. The area of concern for ecological risks in sediment includes all sediments within the HBHA Pond. Based on the arsenic PRG of 273 mg/kg, the in-place volume estimate of contaminated sediments in the HBHA Pond that are exceeding the PRG is approximately 9,400 cubic yards. This preliminary volume estimate is based on previous data collected in the HBHA Pond that showed the average sediment thickness was approximately 41 centimeters and the estimated sediment volume 7,400 cubic meters ((Davis, A., et al, 1996). This original estimate only represented the volume of “black ooze” sediment. However, more recent studies conducted to support the MSGRP RI indicate that sediment contamination is not exclusive to the “black ooze”, but rather, is ubiquitous within the entire 5-acre pond (TtNUS, 2005a). (see Figure 2-5a).

Sediment areas identified within the Wells G&H wetland and Cranberry Bog Conservation Area included unacceptable exposures to sediments considered accessible (i.e. within 30 feet of the edge of the Wells G&H wetland and within the bog irrigation channels, respectively). Volume estimates assumed that remediation would be required to a depth of 2 feet at all sample locations that exceeded the arsenic PRG of 230 mg/kg for the Cranberry Bog Conservation Area and 300 mg/kg of arsenic for stations within the Wells G&H wetland. In each case, the area of remediation was bounded by either a sample location that was below the PRG or by encroachment upon another exposure station. (Figures 2-5b and 2-5c, respectively)

Sediment core areas were assumed to be isolated areas. Volume estimates assumed that remediation efforts would be centered around the sediment core sample location exceeding the arsenic PRG and extend to the next sediment core sample location exhibiting arsenic concentrations below the PRG. In the case of the Wells G&H wetland area, based on available sediment data, it is assumed the approximately the entire wetland will require remediation (See Figure 2-5d). Depths of sediment removal are estimated at 2 feet on average in the vicinity of SC02 and 3 feet on average in the Wells G&H wetland.

The following is a summary of volumes that will be addressed by the general response actions that are evaluated for the FS.

Location	Sediment Sampling Station(s) Showing Human Health or Ecological Risk	Estimated Volume Contaminated Sediment
HBHA Pond	HBHA Pond	9,400 cubic yards
Wells G&H Wetland	13/TT-27, WH, NT-3,	2,200 cubic yards
Cranberry Bog Conservation Area	CB-03	300 cubic yards
Sediment Core Areas	SC02, SC05, SC06, SC08	160,000 cubic yards

2.3.4 General Response Actions and Volume of Surface Water

Table 2-6 presents a summary of the RAOs and general response actions identified for surface water, along with an initial identification of the general remedial technology types and process options that correspond to each general response action. Since groundwater discharge to the HBHA Pond and is impacting surface water, the general response actions selected are dependent upon the general response actions selected for groundwater. For example, a surface water treatment alternative would only be necessary if the contaminated groundwater was not addressed and allowed to continue discharging into the HBHA Pond surface water. These dependent relationships are further evaluated and discussed in Sections 3.0 and 4.0. The general response actions that were evaluated for the remediation of surface water include the following:

- No Action (required by CERCLA)
- Limited Action
- Containment
- Removal
- Treatment

The technology types and process options identified on Table 2-10 will be the candidate technologies for the preliminary screening that is described in Section 3.0.

As described in Section 2.2.4, the ecological risk assessment identified areas in the deeper portions of the HBHA Pond at the groundwater discharge zone where the concentration of benzene and arsenic present unacceptable risks to aquatic organisms. Surface water data within this zone is limited. The estimated contaminated groundwater discharge area is depicted in Figure 2-6.

2.4 <u>Identification and Screening of Technologies and Process Options</u>

This section presents a description of the preliminary screening and the detailed evaluations of technologies and process options for remediation of soil, sediment, surface water, and groundwater at the Industri-plex Superfund Site.

2.4.1 Preliminary Screening of Technologies and Process Options

Potential remedial technologies and process options were identified and screened according to their overall applicability (technical implementability) to each contaminated medium, the contaminants of concern (arsenic, benzene, naphthalene, 1,2-dichloroethane, TCE), and the site-specific conditions present at the Industri-plex Superfund Site. No cleanup is required for benzo(a)pyrene since all detected concentrations were below background concentrations. The purpose of this screening effort is to investigate all of the available technologies and process options and to eliminate those obviously not applicable to the Site, based on the established remedial action objectives and general response actions of Sections 2.2 and 2.3, respectively. Technology identification considered the demonstrated performance of each technology given the site conditions and COCs.

The preliminary screening of technologies is presented by medium on Tables 2-7, 2-8, 2-9, and 2-10. These tables present the technologies available to address soil, sediment, groundwater, and surface water contamination, grouped by general response action. A brief description of the technology is provided and a determination is made to either retain or eliminate the technology based on the evaluation of its technical implementability. A brief description of the rationale that was used to eliminate technologies is also provided. The remedial technologies that are retained from this screening are further evaluated as described in Section 2.4.2.

2.4.2 Evaluation of Technologies and Process Options

A detailed evaluation of technologies and process options that were retained in the preliminary screening step is conducted to further focus the alternatives development process. In this step, process options are evaluated with respect to other processes in the same technology category. One representative process option is selected, if possible, for each technology type, to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedy selection or remedial design.

The evaluation of technologies and process options utilizes three criteria: effectiveness, implementability, and relative cost. The *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988) suggests that this evaluation focus on the effectiveness criterion, with less emphasis directed at the implementability and relative cost criteria.

Brief definitions of effectiveness, implementability, and relative cost, as they apply to the evaluation process, follow.

- Effectiveness - This criterion focuses on the potential effectiveness of process options in handling the estimated volume of media and meeting the remediation goals; the potential impacts to human health and the environment during construction and implementation; and how proven and reliable the process is with respect to the contaminants and conditions at the Site.

- Implementability - The implementability evaluation encompasses both the technical and institutional feasibility of implementing a process. Technical implementability was used in Section 2.4.1 as an initial screen of technology types and process options, to eliminate those that are clearly ineffective or unworkable at a site. Therefore, this subsequent, more detailed evaluation of process options places greater emphasis on the institutional aspects of implementability, such as the ability to obtain permits, availability of treatment, storage, and disposal services, and availability of necessary equipment and resources.

- Cost - Cost plays a limited role in this screening. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to the other options in the same technology type. If there is only one process option, costs are compared to other candidate technologies.

The evaluations of technologies and process options for each medium are presented on Tables 2-10, 2-11, 2-12, and 2-13. The technologies that were retained from this evaluation are described further in Section 2.4.3.

2.4.3 Selection of Technologies and Process Options

This section presents a summary of the evaluation of technologies for each contaminated medium, and selects the technologies and process options that will be retained for alternative development and detailed analysis. The development of alternatives and detailed analysis of alternatives will be conducted in Sections 3.0 and 4.0, respectively.

2.4.3.1 Soil Technologies and Process Options

The areas of concern for soil, where human health risks to future site users were identified due to elevated concentrations of arsenic, are located within the former Mishawum Lake bed to the east of the Halls Brook Holding Area. Contaminated surface soils requiring remediation (between 0 and 3 feet bgs) are located in the vicinity of sampling station SO-13, SO-14, and SO-16. Contaminated subsurface soils are located in the vicinity of soil sampling stations SO-3, SO-11, SO-13, and SO-14 at depths of approximately 3 to 15 feet bgs.

Soil technologies and process options were evaluated based on their ability to achieve RAOs for soil. Technologies and process options for soil that were retained through the preliminary and initial screening process include no action (as required by CERCLA), institutional controls, monitored natural attenuation, excavation, solidification/stabilization, on-site reuse, and off-site disposal. The development of remedial alternatives for soil will employ each of these process options individually or in combination with another process option.

2.4.3.2 Groundwater Technologies and Process Options

As stated previously, the area of concern for groundwater, where contamination in groundwater was determined to present human health risks and hazards above risk management criteria to future site users, includes an area of arsenic/benzene contamination located in the Industri-plex Site/HBHA Pond area in the Northern Study Area and an area of benzene contamination at the West Hide Pile. Other organic contaminants in groundwater that present risk or hazard above risk management criteria include TCE and naphthalene. Both of these plumes generally coincide with the benzene plume. One isolated detection of 1,2-dichloroethane, located within the benzene contaminant plume was also identified as a potential human health risk.

Groundwater technologies and process options were evaluated based on their ability to reduce or eliminate potential human health risks due to direct contact with contaminants in groundwater. The technologies and process options that were retained through the initial screening include the following:

- No Action
- Limited Actions
  - Institutional Controls
  - Groundwater Monitoring
- Containment/Extraction Technologies
  - Vertical Extraction Wells
- Ex-Situ Treatment Technologies
  - Equalization
  - Dewatering
  - Sedimentation
  - Filtration
  - Reverse Osmosis
  - Air Stripping
  - Adsorption
  - Ion Exchange
  - Chemical Oxidation
  - Neutralization
  - Precipitation/Co-precipitation
  - Flocculation
- Discharge Technologies
  - Infiltration Gallery
  - Surface Water Discharge
- In-Situ Treatment Technologies
  - Monitored Natural Attenuation
  - Permeable Reactive Barrier
  - In-Situ Chemical Oxidation
  - Enhanced Bioremediation

Representative treatment technologies were selected for the development and evaluation of remedial alternatives. The representative ex-situ treatment process that will be evaluated for the treatment of the arsenic/benzene contaminant plume will include equalization, chemical oxidation, precipitation/coprecipitation, and adsorption. One passive in-situ treatment technology (permeable reactive barrier) and one active in-situ treatment technology (enhanced bioremediation) will be evaluated for the treatment of groundwater where no extraction occurs.

These representative technologies will be included in the range of alternatives that will be developed and evaluated in Section 3.0 of this FS.

2.4.3.3 Sediment Technologies and Process Options

The areas of concern for sediment, where contamination in sediment was determined to present current or future human health risks and hazards above risk management criteria, include isolated regions of sediment contamination located in the accessible portions of the Wells G&H Wetland and Cranberry Bog Conservation Area; and sediment cores collected from deep sediments that were collected to evaluate future risks associated with a dredging scenario. The area of concern for ecological risk includes the sediments in the HBHA Pond. The migration of arsenic contaminated sediments from upstream sources (HBHA Pond) to downstream depositional areas is also of concern from a human health perspective.

Sediment technologies and process options were evaluated based on their ability to reduce or eliminate potential human health risks due to direct contact with contaminants, their ability to mitigate ecological risks in the HBHA Pond, and their ability to mitigate the transport of contaminated sediment downstream with the flow of surface water. The sediment technologies and process options that were retained through the initial screening include the following:

- No Action (as required by CERCLA),
- Limited Actions
    - Institutional Controls
    - Periodic Monitoring
    - Monitored Natural Recovery/Enhanced Natural Recovery
- Containment/Stormwater Control Technologies
    - Silt Curtain/Silt Screen
    - Subaqueous Cap
    - Sediment Retention
    - Stormwater Bypass
- Removal Technologies
    - Mechanical Dredging
    - Hydraulic Dredging
    - Bulk Mechanical Excavation

- Treatment Technologies
    - Dewatering
    - Solidification/Stabilization
- Disposal Options
    - On-Site Reuse
    - Off-Site Landfill Disposal

In Section 3.0, each of the above technologies will be included in the range of alternatives that are developed and evaluated for the remediation of sediment. The one exception will be that hydraulic dredging will be evaluated as the representative method for the removal of submerged sediments and mechanical excavation will be evaluated as the representative method for the removal of sediments that are not submerged. Hydraulic dredging was selected over mechanical dredging due to the fact that sediment in the HBHA Pond has a very low solids content, which makes it amenable to this type of dredging. The use of hydraulic dredging will minimize the amount of sediment that is suspended into surface waters during dredging.

2.4.3.4 Surface Water Technologies and Process Options

The area of concern for surface water, where contamination in surface water was determined to present unacceptable ecological risks to benthic invertebrates, includes the deeper portions only of the surface water within the HBHA Pond. Arsenic and benzene are contaminants of concern for deep surface water throughout the HBHA Pond. Surface water also represents the principal transport mechanism for soluble arsenic and arsenic-contaminated suspended solids that facilitates the migration of arsenic to downstream depositional areas.

Surface water technologies and process options were evaluated based on their ability to reduce or eliminate potential ecological risks due to exposure to contaminants in surface water. Since the surface water in this zone is the result of direct groundwater discharges, the technologies are similar and interrelated. If groundwater remedies are selected, the need for surface water treatment may not be required. The technologies and process options that were retained through the initial screening include the following:

- No Action
- Limited Actions

- Institutional Controls
- Surface Water Monitoring
- Provide Alternate Habitat (in the event that the HBHA Pond is used as a component of the remedy)

Representative treatment technologies were selected for the development and evaluation of remedial alternatives. No viable remedial alternatives were retained for containment or treatment of contaminated surface water. The representative limited actions that will be evaluated are a combination of institutional controls with monitoring and providing an alternate habitat. These representative technologies will be included in the range of alternatives that will be developed and evaluated in Section 3.0 of this FS.

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

This section presents the rationale for developing remedial action alternatives that address the remedial action objectives, and describes the remedial alternatives that will be evaluated for each of the environmental media and areas-of-concern that were identified in Section 2.0. Relevant statutes and policies were reviewed and identified to help formulate the range of remedial alternatives. The alternatives were developed and screened in accordance with the National Oil and Hazardous Substances Contingency Plan (NCP; 40 CFR 300.430) and the *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, October 1988).

The NCP encourages developing alternatives that favor treatment technologies to address principal threats and alternatives that employ engineering controls to address relatively low long-term threats. Additionally, the NCP suggests developing a range of treatment alternatives, including one or more engineering control alternatives (such as containment), one or more innovative treatment alternatives, and the baseline no action alternative. The EPA RI/FS guidance provides detailed descriptions on formulating, screening, and selecting remedial alternatives for more detailed evaluations. The alternatives development process that is documented in this section follows this guidance.

Section 3.1 presents the rationale for the development of remedial action alternatives for each contaminated media. Sections 3.2, 3.3, 3.4, and 3.5 present the descriptions of remedial action alternatives for soil, groundwater, sediment, and surface water, respectively. In Section 3.6, the screening of remedial alternatives is presented by medium and alternatives are selected for the detailed analysis. The detailed analysis of alternatives is presented in Section 4.0.

3.1 <u>Rationale for Development of Remedial Action Alternatives</u>

This section presents a description of the rationale that was used to develop remedial action alternatives to address contaminated media at the Site. The considerations described below were each incorporated into the alternatives development process for each medium or area of concern.

3.1.1 Protection of Human Health Considerations

As presented in Section 1.0, the baseline human health risk assessment evaluated the potential exposure to contaminants in soil by future adult and child receptors. Cancer risks and/or non-cancer hazards in excess of risk management criteria were identified for future adult construction workers and future day care children. The primary risk contributor is elevated concentrations of arsenic in surface and subsurface soil samples collected from the former Mishawum Lake bed area.

The baseline human health risk assessment evaluated the potential risks and hazards to future adult receptors (industrial worker and construction worker) exposed to site groundwater. It was determined that if groundwater from a contaminant plume located to the north and east of the HBHA Pond (see Figure 1-5) were to be used as industrial process water or as wash water for a warm water car wash, then excess carcinogenic risks would exceed EPA's target risk range of 10^{-4} to 10^{-6} and/or a Hazard Index of 1.0. Risk and hazard estimates are presented in the MSGRP Remedial Investigation Report (TtNUS, 2005).

The baseline human health risk assessment evaluated the risks and hazards to current and future adult and child receptors from direct contact with contaminated sediment. Risks and hazards in excess of risk management criteria were estimated for sediment located in the Halls Brook Holding Area, the Wells G&H wetland, and the Cranberry Bog Conservation Area. As depicted on Figure 1-4, the exposure points for these risks consisted of several areas within sediment sampling stations in these areas of concern. Sediments near the edge of wetlands were considered accessible to recreational humans, extending up to 30 feet into the wetlands. Sediment areas identified by sediment core locations, which are located in the deeper interior areas of the wetlands and within the river channel, were not considered accessible to humans except under a potential future dredging scenario where construction workers could be exposed.

Chemical-specific PRGs were developed using assumptions and equations consistent with those used in the human health risk assessment to determine the concentration of the COCs that would provide a level of risk to future receptors within the target risk range. The remedial alternatives developed in this FS will address the chemicals present in excess of these PRGs that pose potential carcinogenic risks and non-carcinogenic hazards to human health through current and future exposures to contaminated soil, groundwater, and sediment in these areas of Site. Each remedial alternative was to be evaluated based on its ability to address the protection of human health through either the elimination of these exposure pathways or reduction of the exposure point contaminant concentrations.

3.1.2 Protection of Ecological Receptors

Based on the results of the ecological risk assessment and a risk management determination made by EPA in February 2005, the HBHA Pond is the only habitat area with unacceptable ecological risks that will be addressed by the FS. The ecological risk assessment identified potential risks to benthic invertebrates exposed to high levels of metals, particularly arsenic, in the sediments of HBHA Pond. The ecological risk assessment also identified unacceptable risks to aquatic organisms due to arsenic in deep surface water throughout the HBHA Pond and benzene in deep surface water associated with groundwater discharge at the northern portion of the HBHA Pond.

Chemical-specific PRGs were developed based on concentrations of the contaminants of concern that would reduce or eliminate the exposure to aquatic receptors and benthic invertebrates at levels associated with adverse ecological effects. The remedial alternatives developed in this FS will address the chemicals present in excess of these PRGs that pose potential risks to aquatic receptors in the HBHA Pond through exposures to contaminated sediment and surface water. Each remedial alternative was evaluated based on its ability to address the protection of ecological resources through either the elimination of these exposure pathways or replacement of the habitat through mitigation.

Treatment or containment alternatives for sediment contaminated with metals (primarily arsenic) in the pond were evaluated based on their ability to mitigate ecological risks and prevent further downstream migration of contaminated sediment. Surface water technologies and process options were evaluated based on their ability to reduce or eliminate potential ecological risks due to exposure to contaminants in surface water. Since the risks associated with exposures to surface water in the HBHA Pond are related to groundwater discharges, the development and evaluation of alternatives for surface water is highly dependent upon the technologies that are employed to address groundwater. For this reason, discussions of surface water alternatives will include contingencies that involve references to groundwater alternatives.

3.1.3 Floodplain Considerations

Most of the areas of concern for soil and sediment contamination are located within the 100-year floodplain of the Aberjona River. In fact, flooding of the Aberjona River was evaluated as a transport mechanism for sediment all along the Aberjona River and Halls Brook Holding Area (HBHA). Residential exposures to floodplain soils were also evaluated as part of the human health risk assessment for the Southern Study Area. The presence of the floodplains and the flood storage capacity at the Site needs to be considered in the formulation of remedial alternatives. Executive Order 11988 requires that remedial alternatives be evaluated to avoid adverse effects and incompatible development in the floodplains, and to minimize potential harm to floodplains if the only practicable alternative requires siting an action in a floodplain. The order also provides opportunities for public review.

For the purpose of the FS, the potential impact (loss of flood storage capacity) of each alternative was evaluated. Once a remedy is selected for the Site, a formal floodplains assessment needs to be completed to accurately estimate impacts to the floodplain capacity, effects of construction on the floodway, and whether there are impedances to flood conveyance. Based on those findings, options for developing compensatory flood storage capacity may be developed.

3.1.4 Wetlands Considerations

As discussed in Sections 1.0 and 2.0, the majority of the metals contamination within the Study Area is located in wetland areas within or adjacent to surface water bodies such as the HBHA Pond, Halls Brook Holding Area, and the Aberjona River. In order to attain clean-up levels that would be protective of human and/or ecological receptors, active remedial actions may be required in the wetlands including excavation, treatment, or containment.

Active remediation would likely result in the unavoidable loss of the on-site wetlands. As described in the revised Memorandum of Agreement between the EPA and the Department of the Army Concerning the Determination of Mitigation Under the Clean Water Act Section 404(b)(1) Guidelines (MOA), dated March 12, 1990, three general types of wetlands mitigation are compatible with the requirements of the guidelines: avoidance, minimization, and compensatory mitigation. Where practical, remedial alternatives will strive to avoid and minimize wetland losses, but if active remediation is required in wetland areas, the loss of wetland habitat is inevitable. In these cases, compensatory mitigation would be the appropriate action.

The preferred type of compensatory mitigation is on-site restoration of existing degraded wetlands or creation of man-made wetlands. If on-site compensatory mitigation is not practicable, then the off-site restoration of existing degraded wetlands or creation of man-made wetlands would be undertaken in the same geographic area; for instance, in close physical proximity to and, to the extent possible, within the same watershed as the original wetlands. Restoration of existing degraded wetlands is preferred over creation of man-made wetlands because of uncertainty regarding the success of man-made wetlands. The development of remedial alternatives will consider the potential impacts of each option and the actions necessary to mitigate the potential loss of wetlands.

3.2 Development of Remedial Alternatives for Soil

This section provides descriptions of remedial alternatives that would address areas where risks and hazards in excess of risk management criteria were identified based on potential future exposures to arsenic in soil. These alternatives were developed from the technologies and process options that were retained in Section 2.4.3.1 of the FS. The descriptions presented below provide a general description of the remedial alternatives that are considered for soil. The screening of remedial alternatives for soil is presented in Section 3.6.1.

3.2.1 Soil Alternative 1: No Action

The No Action alternative was developed as a baseline case, as required by the NCP, to which all other alternatives may be compared. Under this alternative, it is assumed that no action would be taken to reduce the toxicity, mobility, or volume of contaminated soil within the former Mishawum Lake bed.

The No Action alternative would not be effective at achieving the RAOs for soil since it would not limit future human exposures to contaminated soil. There would be no treatment, containment, or removal of soil that is contaminated with arsenic, and potential future risks to human receptors would remain. As required by CERCLA, a review of site conditions and risks would be conducted every 5 years since contamination would remain on site above levels that allow for unlimited use and unrestricted exposure.

3.2.2 Soil Alternative 2: Monitoring with Institutional Controls

Soil Alternative 2 was developed as an alternative that does not involve treatment or removal, but provides protection of human health by preventing or controlling potential exposures to contaminated soil through institutional controls. Under this alternative, institutional controls would be implemented to prevent future exposures to contaminated soil in the former Mishawum Lake bed area. A pre-design investigation would be required to delineate the area requiring application of institutional controls. Currently, groundwater conditions at this area do not pose a risk or hazard to human health or a risk to the environment. Monitoring would ensure that groundwater conditions are periodically evaluated to determine if these conditions change as a result of the contaminated soils that would be left in-place.

Institutional controls would take the form of land-use restrictions, specifically the prohibition of use by a day care facility and prohibitions on excavation in this area, including paved areas and below building foundations, unless adequate precautions (engineering controls, personal protective equipment [PPE]) were taken to minimize or prevent direct contact with contaminated soil during removal activities. These types of controls would be designed to address the potential human health risks that were identified under the future use scenarios that were evaluated for the former Mishawum Lake bed area.

Soil Alternative 2 does not involve any actions that will reduce the toxicity, mobility, or volume of contamination in soil. The only on-site activities that would be conducted under this alternative are long-term monitoring of environmental media and periodic reviews of site conditions and risks. As required by CERCLA, a review of site conditions and risks would be conducted every 5 years since contamination would remain on site above levels that allow for unlimited use and unrestricted exposure.

3.2.3 Soil Alternative 3: Permeable Cover and Monitoring with Institutional Controls

Soil Alternative 3 was developed as an alternative that does not involve treatment or removal, but provides protection of human health by preventing or controlling potential exposures to contaminated soil through the construction of a protective barrier or cap over the contaminated soils. Under this alternative, a permeable cover would be constructed to prevent future exposures to contaminated soil in the former Mishawum Lake bed area. This alternative would also require the implementation of institutional controls to require periodic inspections and long-term maintenance of the cover to preserve its integrity, and regulations on future construction methods and procedures if the cover must be breached. A pre-design investigation would be required to delineate the area requiring installation of the permeable cover. The current estimated areas are based on widely spaced data and the final areas could vary significantly.

3.2.3.1 <u>Limited Soil Excavation</u>

This alternative also requires the limited excavation of soils to accommodate the construction and completion of the permeable cover at existing grades. Excavated soils would be disposed off-site at a permitted facility. A soil stockpiling area would be constructed at a location to be determined within the areas of concern. The soil stockpiling areas would be necessary to stage excavated soil while it is being characterized for disposal. The stockpiling area would consist of lined, bermed areas surrounded by erosion controls to prevent the migration of contaminants due to runoff during storm events. Contaminated soil stockpiles would also be covered to prevent migration of contaminants from wind erosion. Underliners would be installed at the stockpiling area to prevent contact between contaminated soil and the underlying ground surface. Once characterized and accepted at the designated disposal facility, the soils would be loaded into trucks and shipped offsite.

Erosion and sedimentation control measures would be installed at each area where excavation or any other earth-moving activity occurs. Typically, these measures would include the installation of silt fence and/or straw bales at the perimeter of all work areas and adjacent to any wetland or surface water features that could potentially be impacted by runoff from the work site. The scale of these measures will vary depending upon the size of the excavation area and its proximity to sensitive environmental areas.

3.2.3.2 Permeable Cover Construction

A permeable cover would likely take the form of a permeable engineered multi-media cap over the contaminated soil. This approach has been successfully used at the Industri-plex Site for the remedy of soils contaminated with heavy metals. Existing asphalt paved areas and building foundations/slabs would be evaluated to determine if they are suitable as cover that is functionally equivalent to the proposed cap. If determined to be "equivalent cover", these area will be left as is (or repaired), but included in the institutional controls along with the areas receiving an engineered cover, subject to long-term maintenance and management.

Soil Alternative 3 does not involve any actions that will reduce the toxicity of contamination in soil due to contaminated soils remaining in place below the permeable cover. A limited volume of contaminated surface soils would be removed and disposed offsite at an approved licensed disposal facility in order to facilitate construction of the cap without affecting the existing grades. Once the permeable cover was installed on-site, activities that would be conducted under this alternative are long-term maintenance, long-term monitoring of environmental media and periodic reviews of site conditions and risks. As required by CERCLA, a review of site conditions and risks would be conducted every 5 years since contamination would remain on site above levels that allow for unlimited use and unrestricted exposure.

3.2.4 Soil Alternative 4: Excavation and Off-Site Disposal

Soil Alternative 4 features the excavation of contaminated soil from the former Mishawum Lake bed area and disposal of this soil at an approved, licensed, off-site disposal facility. Excavation of contaminated soil, and backfilling with clean soil, would be protective of human health by eliminating potential future human health risks and hazards associated with direct contact with contaminated soil. The following sections present a description of the major components of Alternative 4.

3.2.4.1 Site Preparation

A pre-design investigation would be required to delineate the area requiring excavation and disposal. The current estimated areas are based on widely spaced data and the final areas and volumes could vary significantly. Site preparation would be necessary to implement contaminated soil excavations within the former Mishawum Lake bed. Since the sampling locations where contamination was identified are readily accessible to excavation equipment, clearing and grubbing of vegetation should be minimal. Much of the area in this portion of the site is covered with asphalt pavement, therefore ground stabilization is not likely to be necessary to accommodate excavation equipment.

Erosion and sedimentation control measures would be installed at each area where excavation or any other earth-moving activity occurs. Typically, these measures will include the installation of silt fence and/or straw bales at the perimeter of all work areas and adjacent to any wetland or surface water features that could potentially be impacted by runoff from the work site. The scale of these measures will vary depending upon the size of the excavation area and its proximity to sensitive environmental areas.

A soil stockpiling area would be constructed at a location to be determined within the areas of concern. The soil stockpiling areas would be necessary to stage excavated soil while it is being characterized for disposal. The stockpiling area would consist of bermed areas surrounded by erosion controls to prevent the migration of contaminants due to runoff during storm events. Contaminated soil stockpiles would also be covered to prevent migration of contaminants from wind erosion. Underliners would be installed at the stockpiling area to prevent contact between contaminated soil and the underlying ground surface. Once characterized and accepted at the designated disposal facility, the soils would be loaded into trucks and shipped offsite.

Site preparation for excavation would also involve the establishment of decontamination facilities to prevent the transport of contamination from the excavation sites. Since the work areas are within heavily developed commercial and light industrial areas, decontamination of all equipment and personnel leaving each excavation site would be a priority during implementation of the excavations to minimize short-term impacts to the community from the remedial action. For this purpose, a heavy equipment decontamination pad would be constructed at each site access point to prevent the transport of contaminated soil into public or private roadways. Decontamination pads typically consist of a gravel or concrete pad designed to capture and drain decontamination fluids into a sump. Decontamination is accomplished using pressure washers to wash the tires and frame of trucks as they leave the site. Decontamination fluids are typically containerized, characterized for disposal, and ultimately shipped to an approved licensed disposal facility.

3.2.4.2 Contaminated Soil Excavation

As stated previously, Soil Alternative 3 would involve the excavation of contaminated soil located within the former Mishawum Lake bed area to the vertical and horizontal limits required to remove the entire volume of soil that might present future risks and hazards to human receptors. For surface soil, the vertical limit is assumed to be 3 feet. For subsurface soils, the vertical limit is assumed to be 15 feet. After site preparation activities have been completed and prior to the commencement of excavation, a site survey would be conducted to identify and mark the preliminary limits of contaminated soil (see Figure 2-3A for estimated surface soil horizontal limits and Figure 2-3B for the estimated subsurface horizontal limits). Excavation areas would be marked in the field using wooden stakes, pin flags, or white spray paint. Appropriate investigations and surveys would be conducted to identify all underground utilities prior to excavation.

Excavation of soil would be accomplished using a hydraulic excavator. Excavated soil would be transferred from the excavator bucket directly into dump trucks or dump trailers at the point of excavation. Dump trucks would transport excavated soil from the excavation site to the soil stockpiling area, where it will be temporarily stored until the proper disposal requirements are determined.

After the removal of soil to the vertical and horizontal limits delineated above, a series of cleanup confirmation soil samples would be collected from each soil excavation. Confirmation samples would be collected from the sidewalls of each excavation at regular intervals to verify that the full horizontal extent of contaminated soil has been removed from the site. Soil samples would be analyzed for the presence of arsenic using a portable field x-ray fluorescence (XRF) instrument with approximately 10 percent of the samples analyzed by a laboratory for confirmation. Additional excavation would be performed in the vicinity of any soil sample containing concentrations of arsenic in excess of remediation goals. Additional cleanup confirmation samples would be collected after the additional excavation is complete. This iterative process would continue until all remedial objectives are achieved.

3.2.4.3 Backfill and Site Restoration

Following verification that all contaminated soil has been removed from the site, geotechnical materials, if applicable, would be installed in the excavations, and the excavations would be backfilled using clean soil. Backfill material would be obtained from a local source, analyzed to certify that it is free of contaminants, and delivered to the site using dump trucks or dump trailers. Backfill material would be dumped directly into the excavations and spread using the excavator or a bulldozer depending on the size of the excavation. Compaction would be accomplished using a vibratory roller or equivalent equipment. Backfill would be spread and compacted in lifts, and density tests would be conducted after each lift to ensure that backfill is being placed according to specifications.

Surface restoration at each property would involve re-establishing the pre-excavation surface features. Vegetated areas would be replanted with the equivalent vegetation that was present prior to excavation. Paved areas would be resurfaced with asphalt pavement or concrete.

3.2.4.4 Waste Characterization and Off-Site Disposal

Excavated and stockpiled soil would ultimately be transported to an off-site disposal facility. Based on the anticipated concentration of arsenic in soil that will be removed, it is assumed that excavated material will be suitable for disposal at a RCRA Subtitle C hazardous waste landfill. In order to confirm the appropriate disposal requirements for excavated soil, waste characterization samples (as required by the disposal facility) will be collected from stockpiled soil. Soil would be transported to offsite treatment and/or disposal facilities using dump trailers with an approximate 20 cubic yard capacity (80,000 pound gross vehicle weight).

3.2.5 Soil Alternative 5: Excavation, Treatment, and On-Site Reuse

Soil Alternative 5 features the excavation of contaminated soil from the former Mishawum Lake bed area, treatment of soil using acid extraction, and placement/re-use of treated soil as backfill material. The following sections provide a description of the major components of Soil Alternative 5.

3.2.5.1 Site Preparation, Excavation, and Temporary Storage of Soil

The site preparation, excavation, and soil stockpiling procedures for contaminated soil under Soil Alternative 5 would be the same as described for Soil Alternative 4. From the standpoint of soil removal and temporary storage of excavated soil at the former Mishawum Lake bed area, Soil Alternative 5 is identical to Soil Alternative 4. The stockpiling area may be larger to accommodate the soil treatment processing equipment.

3.2.5.2 Treatment and Reuse of Contaminated Soil

The primary difference between Soil Alternatives 4 and 5 is the onsite treatment of excavated soil. Under Alternative 5, contaminated soil would be transported to a stockpiling/treatment area, where it would be treated to remove arsenic, rather than characterized for off-site transportation and disposal.

Under Soil Alternative 5, arsenic would be removed from the excavated soil using a treatment train approach that includes soil pre-treatment, acid extraction, rinsing, and dewatering. These facilities would be mobilized to the site and a designated treatment area would be constructed to process and treat contaminated soils.

The first step in the treatment process would be to screen soils to remove coarse solids. Overflow from this process would be sampled to determine if it contains unacceptable concentrations of arsenic, and would be utilized as backfill material (if clean) or transported to an off-site facility for disposal.

Next the soil would be fed into a batch reactor and acid is mixed in to promote contact between soil and the acid extractant. The residence time in the unit will vary depending on the soil type and contaminant concentrations, but generally ranges between 10 and 40 minutes. The soil-extractant mixture is continuously pumped out of the mixing tank in slurry form, and the soil and extractant are separated using hydrocyclones.

When extraction is complete, the solids are transferred to the rinse system. The soils are rinsed with water to remove entrained acid and arsenic. The extraction solution and rinse waters are regenerated using commercially available precipitants, such as sodium hydroxide, lime, or other proprietary formulations, along with a flocculent that removes the arsenic and reforms the acid. During the final step, the soils are dewatered and mixed with lime and fertilizer to neutralize any residual acid.

The soil treated by the acid extraction process would be sampled to ensure that arsenic concentrations have been reduced to acceptable levels and that no unacceptable levels of residual acid remain. Soil can be re-treated if required to achieve remediation goals. If post-treatment characterization samples are acceptable, the treated soil would then be used to backfill the areas from which they were excavated (see Section 3.2.4.3). If some of the treated material is unsuitable to backfill at the site, that material would be transported to an off-site facility for disposal and clean fill would be purchased to backfill excavations, as needed. The aqueous waste stream from the batch reactor (to which arsenic will have been transferred) would be captured, containerized, and properly treated or disposed offsite. Upon complete processing of contaminated soil, the batch reactor would be demobilized from the site.

3.3 Development of Remedial Alternatives for Groundwater

This section describes the remedial alternatives that would address areas where risks and hazards in excess of risk management criteria were identified based on potential future exposures to groundwater. In addition, groundwater discharges to the HBHA Pond result in unacceptable ecological risks to benthic invertebrates in sediments, unacceptable risks to benthic aquatic organisms in deeper surface water, and also represents a source of arsenic to downstream depositional areas. These alternatives were developed from the technologies and process options that were retained in Section 2.4.3.2 of the FS. The descriptions presented below provide a general description of the remedial alternatives that are considered for groundwater. The screening of alternatives for groundwater is presented in Section 3.6.2.

3.3.1 Alternative GW-1: No Action

The No Action alternative was developed as a baseline case, as required by the NCP, to which all other alternatives may be compared. Under this alternative, it is assumed that no action would be taken to reduce the toxicity, mobility, or volume of contaminated groundwater at the Industri-plex MSGRP Study Area.

The No Action alternative would not limit potential human exposure to contaminated groundwater, and would not prevent future discharges of contaminated groundwater to surface water bodies at the Site. There would be no treatment of groundwater that is contaminated with arsenic, benzene, TCE, naphthalene, or 1,2-dichloroethane; and there would be no measures taken to restrict the future use of groundwater that is contaminated with these substances. Groundwater that is contaminated with arsenic would continue to migrate southward with the flow of groundwater, and would continue to discharge into the HBHA Pond, Aberjona River, and adjacent wetlands, providing a continuing source of contamination to surface water and sediments in these areas. As required by CERCLA, a review of site conditions and risks would be conducted every 5 years since contamination would remain on site above levels that allow for unlimited use and unrestricted exposure.

3.3.2 Alternative GW-2: Pond Intercept and Monitoring with Institutional Controls

Alternative GW-2 was developed as an alternative that intercepts groundwater discharge at the HBHA Pond with no active treatment, but provides protection of human health by preventing or controlling potential exposures to contaminated groundwater through institutional controls. The activities that would be conducted under this alternative include: institutional controls; long-term monitoring of groundwater, surface water, and sediments to evaluate contaminant status and migration; and a review of site conditions and risks every 5 years.

As presented in the baseline human health risk assessment, human health risks and hazards above risk management criteria from direct contact with contaminated groundwater would result from future use of site groundwater such as industrial process water or as wash water in a car wash (adult industrial worker and adult car wash worker exposure scenarios). Alternative GW-2 would strive to limit human exposure to contaminated groundwater through deed restrictions, which would prohibit the use of site groundwater for activities that could pose a future human health risk.

Alone, Alternative GW-2 would not minimize discharge of contaminated groundwater to the HBHA Pond, Aberjona River, or adjacent wetlands; but would attempt to limit human exposure to the contaminants present in the groundwater at the site. Alternative GW-2 would use the HBHA Pond to intercept the groundwater as it is discharged to the pond and where natural processes are degrading and sequestering the contaminants of concern. Alternative GW-2 coupled with an HBHA Pond sediment alternative that prevents disruption of the surface water chemocline within the Pond would further minimize southward migration of contaminants to areas downstream of the HBHA Pond. Under this alternative, environmental monitoring would be conducted on a periodic basis to provide the regulatory agencies with the appropriate data to determine whether additional actions are needed.

3.3.3 Alternative GW-3: Plume Intercept, Groundwater Extraction, Treatment, Discharge, and Monitoring with Institutional Controls

Alternative GW-3 is an active groundwater extraction and treatment alternative. This alternative would consist of installing a groundwater extraction system to intercept, collect, and treat contaminated groundwater from the overburden aquifer prior to discharge to the HBHA Pond. The implementation of Alternative GW-3 would prevent continued migration of groundwater contaminants into the HBHA Pond through hydraulic containment, but would not reduce groundwater contaminant concentrations within the treatment zone to levels that are within the target risk range due to the widespread presence of metals and organics at the Industri-plex Site. Instead, Alternative GW-3 would provide protection of human health by preventing or controlling potential exposures to contaminated groundwater through the use of institutional controls placed on properties located within the contaminated groundwater plume. Groundwater monitoring would be conducted on a periodic basis to provide the regulatory agencies with the appropriate data to determine whether additional actions are needed

The groundwater extraction system that would be most effective at the Site would consist of a series of vertical extraction wells placed in a pattern that enables complete hydraulic capture of the contaminated portions of the aquifer discharging into the HBHA Pond while minimizing the amount of uncontaminated groundwater that is extracted. The extraction system would also include a network of underground pipe that would convey extracted groundwater to a central treatment location, where ex-situ treatment of groundwater would be performed.

Contaminated groundwater that is extracted would be treated by using a treatment train that consists of a series of processes that are applicable to the target contaminants that are being removed. Generally, the treatment train would consist of an equalization tank to control flow into the system and, if necessary, a particle filtration system for the removal of suspended solids. These pre-treatment processes would be followed by contaminant-specific treatment processes. The estimated influent concentration of target contaminants based on the average contaminant concentrations detected in all groundwater samples is as follows:

- arsenic 217 µ/L
- benzene 1,100 µ/L
- 1,2-dichloroethane 0.3 µ/L
- TCE 4 µ/L
- Naphthalene 8 µ/L

Treatment processes for the removal of arsenic would consist of chemical oxidation and precipitation with the addition of potassium permanganate followed by flocculation and clarification. The literature states that this process is reliable to remove arsenic to a concentration in the range of 100 to 150 µg/L. The potassium permanganate would be added to oxidize and precipitate arsenic, as well as other metals that may impact discharge limits such as iron. As needed, pH would be adjusted by the addition of hydrochloric acid or sodium hydroxide to optimize the reaction. The water would then flow to a slow-mixed flocculation tank, where a polyelectrolyte (polymer) would be added to enhance the precipitation of the oxidation reaction products. The discharge from the flocculation tank would flow into a tube settler clarifier where the solids would settle out. The clarified water would then flow through activated carbon filters for the removal of residual organic contaminants. Finally the water would flow to a holding tank for ultimate discharge to a groundwater recharge system or to surface water. Finally, as a polishing step, the water would be filtered through green sand media for further removal of arsenic.

Sludge from the clarifier would be pumped to a gravity thickening tank. The sludge would be thickened under quiescent conditions and supernatant would be pumped off on a regular basis. The thickened sludge solids would be removed periodically and transported for off-site disposal. The hazardous waste characteristics of the sludge stream are uncertain. The concentration of arsenic in the sludge from the oxidation and precipitation process has the potential to generate a TCLP leachate arsenic concentration greater than the RCRA characteristic concentration allowed. However, the arsenic is anticipated to be tightly bound to the iron particulates in the thickened sludge, and sludges from similar waste streams treated by this process have been observed to be non-hazardous.

3.3.4 Alternative GW-4: Plume Intercept, In-Situ Groundwater Treatment, and Monitoring with Institutional Controls

Alternative GW-4 is an in-situ groundwater treatment alternative. The in-situ groundwater treatment strategy that is evaluated for the FS includes two technologies that would be used together to address the principal threats identified in groundwater at the Site. First, oxygen enhancement (in-situ chemical oxidation or in-situ enhanced bioremediation) would be used to treat the organic contaminant source areas located between the East-Central Hide Pile and the South Hide Pile in the vicinity of Atlantic Avenue (benzene, TCE, 1,2-dichloroethane, and naphthalene) and an isolated source area at the West Hide Pile (benzene). Second, a permeable reactive barrier would be constructed along the perimeter of the northern portion of the HBHA Pond to intercept and treat groundwater contaminated with arsenic prior to surface water discharge in the HBHA Pond. Combined, these in-situ treatment processes would decrease organic contaminant concentrations to levels below remediation goals, and intercept and treat arsenic prior to discharge in the HBHA Pond.

Alternative GW-4 would not decrease site-wide arsenic concentrations in groundwater to levels within the target risk range due to the site- wide presence of metals and organics at the Industri-Plex Site. This alternative would only serve to intercept and treat arsenic contaminated groundwater prior to surface water discharge in the HBHA Pond. Alternative GW-4 provides protection of human health by preventing or controlling potential exposures to contaminated groundwater through the use of institutional controls on properties located within the contaminated groundwater plume. Groundwater monitoring would be conducted on a periodic basis to provide the regulatory agencies with the appropriate data to determine whether additional actions are needed.

3.3.4.1 In-Situ Treatment of Benzene-Contaminated Groundwater

Two representative treatment technologies are presented in this section to address benzene contamination in the Northern Study Area. Both alternatives involve the addition of oxygen to the aquifer to promote degradation (chemical or biological) of contaminants without extracting groundwater from the aquifer. The only difference between the two technologies is the type of amendment that would be used to promote in-situ treatment. Each of these alternatives, if designed properly, could decrease groundwater contaminant levels to those that would be protective of human health and the environment. The following sections provide brief descriptions of the components of these technologies as they apply to in-situ treatment of contaminated groundwater at the Site.

Reagent Delivery System

The two in-situ groundwater treatment technologies that will be evaluated are similar in that they both involve liquid delivery systems as a means to apply the treatment reagent to the contaminated groundwater that is being treated. As such, the overall effectiveness of each of these active in-situ processes is primarily dependent upon the ability to deliver the treatment reagent (either chemical oxidizer or oxygen-releasing slurry) to the contaminated areas that are being addressed. In order to successfully implement such a process, a liquid delivery system of adequate size and scope must be designed to cover the entire contaminant plume area.

Liquid delivery systems that are used for in-situ chemical or biological treatment typically consist of wells or trenches where adequate amounts of nutrients, oxygen, or other chemical oxidants are released to the subsurface to circulate throughout the zone of contamination and provide the subsurface conditions necessary to promote contaminant degradation. A liquid delivery system for the purpose of injecting chemical or biological amendments into the contaminated portions of the overburden aquifer would likely consist of a series of wells (or injection points) installed in a grid formation, at fixed intervals, throughout the entire area of groundwater contamination. Injection points can be installed using commonly available direct push drilling techniques with amendments being injected under pressure directly into the aquifer through the direct push boring.

Chemical Oxidation Process

While the injection/application methods for these two treatment amendments are similar, the reagents (and the processes through which they promote contaminant degradation) are very different. Once brought into contact with contaminants, chemical oxidants, such as hydrogen peroxide or potassium permanganate, change the structure of contaminants by breaking apart their chemical bonds and releasing electrons. This is accomplished by introducing the oxidant to the area of organic contamination, which acts as the electron acceptor in this oxidation/reduction reaction. Organic contaminants with double bonds are most vulnerable to this type of reaction, therefore compounds like benzene, toluene, naphthalene, 1,2-

dicholorethane, and TCE are very amenable to destruction though chemical oxidation. If enough oxidant is applied to these contaminants, the resulting chemical reactions will eventually break down the contaminants into compounds commonly found in nature, such as carbon dioxide and water. However, due to the high concentrations of total organic carbon that exist in the subsurface soils at the Industri-plex Site from wetland peat deposits, animal hides, etc., a significantly larger volume of potassium permanganate may be required to be effective in decreasing the chemical contaminants in comparison to an oxidant such as hydrogen peroxide.

Enhanced Bioremediation Process

Several different biological amendments have been developed for the purpose of enhancing the contaminant-degrading activity of indigenous microbes. Bioremediation involves using the natural respiration and digestion processes of microorganisms to decrease levels of organic contaminants in soil and water. Generally, the byproducts of bioremediation of petroleum based organic contaminants such as benzene and toluene are carbon dioxide, water, and biomass. However, This FS will focus on two such proprietary formulations whose function is to affect a slow release of oxygen to the aquifer so that it can be used to increase the rate of aerobic biodegradation.

Regenesis, Inc. (ORC Advanced™) and Panther Technologies (PermeOx® Plus) have each developed proprietary formulations of calcium hydroxide or calcium peroxide that, when hydrated, trigger a slow release of oxygen. This oxygen enhancement provides a subsurface environment that is more amenable to aerobic biodegradation of contaminants by indigenous microbe communities. Petroleum hydrocarbons (such as benzene and toluene) are the most commonly targeted contaminant for these types of bioremediation enhancing agents. Different formulations are available that are designed to slowly release lactic acid to the aquifer, improving conditions for anaerobic degradation and increasing the rate of reductive dechlorination of contaminants such as TCE. A biodegradation by-product of TCE could include vinyl chloride. However, vinyl chloride can be further degraded or detoxified to ethene through continued biodegradation processes. A pre-design investigation would be required to identify the specific formula or combination of formulas and application requirements to achieve the remedial objective.

Groundwater Monitoring and Performance Evaluation

The implementation of an active in-situ groundwater treatment technology such as those proposed for Alternative GW-4 would also involve an extensive groundwater monitoring plan. Quarterly groundwater monitoring would be required upgradient, downgradient, and within the treatment areas to evaluate the effectiveness of the technology and assess progress toward meeting cleanup goals. Sampling events would continue quarterly until all remedial objectives have been met or until measurements and observations of aquifer conditions suggest that the groundwater chemical or biological enhancement reagent has been consumed (most likely indicated by lower dissolved oxygen concentrations).

If groundwater monitoring indicates that the chemical or biological treatment reagent is consumed before remedial goals are met, then additional application of the treatment reagent may be necessary. The additional injection may only be warranted in certain portions of the site, but would involve the same type of capital investment that is made for the initial injection. Continued monitoring would be required to evaluate the performance of the process until cleanup goals have been achieved throughout the entire contaminated area.

3.3.4.2 In-Situ Treatment of Arsenic-Contaminated Groundwater

Alternative GW-4 utilizes a permeable reactive barrier (PRB) to intercept groundwater as it flows toward the HBHA Pond as a means of treating groundwater contaminated with concentrations of arsenic that pose potential future risks to human receptors and risks to ecological receptors following discharge to the HBHA Pond. A PRB could be designed to treat the Site COCs so that groundwater is prevented from transporting contaminants into surface water and sediment in the HBHA Pond. The following sections discuss some of the components of the PRB design as they pertain to the treatment of arsenic-contaminated groundwater that presents human health and ecological risks at the Site.

PRB Configurations

PRBs can be constructed using several configurations, each designed to intercept the entire volume of contaminated groundwater as it flows through the barrier without allowing contaminated groundwater to pass under or around the barrier. The two configurations that will be considered for this FS are the continuous permeable wall and the funnel and gate.

The first, and most commonly constructed, configuration is the continuous permeable wall. In this configuration, the treatment media is distributed across the entire width of the contaminated groundwater plume. Groundwater flow is not manipulated or redirected, but simply allowed to flow in its natural direction at its natural velocity. If a reactive media with sufficiently high permeability is utilized, little or no reduction or redirection of groundwater flow velocity will occur, and the barrier does not need to be “keyed” into a low-permeability zone at its base.

A second commonly used configuration is the funnel and gate. The funnel and gate configuration uses low permeability materials (funnel) to direct groundwater towards the permeable treatment zone (gate). The funnel must extend at least to the entire width of the groundwater plume to ensure that all of the contaminated groundwater is captured and treated. As groundwater is intercepted by the funnel and gate system, the groundwater flow velocity through the treatment media may be increased several times. As a result, the treatment zone must be longer than the continuous wall configuration to retain an adequate contact time between contaminants and the reactive media. Redirection of the groundwater flow path by the funnels in this system creates the risk that groundwater will flow beneath the barrier and continue downgradient untreated. For this reason, funnel and gate barriers typically extend downward into low permeability material to prevent groundwater from passing beneath the barrier.

Treatment Media

The most important factor in the design of a PRB is the selection of reactive materials that will make up its treatment zone. Permeable reactive barriers can be constructed using a variety of materials, meaning that their use may be appropriate to treat a wide variety of contaminant types. Examples of media that have been used for arsenic removal include zero-valent iron (ZVI), limestone, surfactant modified zeolite, and ion exchange resin.

The material used most frequently as treatment media in PRBs is ZVI. ZVI has very high permeability, which enables groundwater to flow through without significantly altering the natural groundwater flow path. As contaminated groundwater flows through and reacts with ZVI, the pH increases and the Eh decreases. These chemical changes promote a variety of processes that impact contaminant concentrations. Increases in pH favor the precipitation of carbonates of calcium and iron as well as insoluble metal hydroxides. Decreases in Eh drive reduction of metals and metalloids with multiple oxidation states. Finally, an increase in the partial pressure of hydrogen in subsurface systems supports the activity of various chemotropic organisms that use hydrogen as an energy source, especially sulfate-reducing bacteria and iron-reducing bacteria (EPA, 2002).

Arsenate [As (V)] ions bind tightly to the iron filings, causing the ZVI to be oxidized to ferrous iron, aerobically or anaerobically in the presence of water, as shown by the following reactions:

- (anaerobic) $Fe^0 + 2H_2O = Fe^{+2} + H_2 + 2OH^-$
- (aerobic) $2Fe^0 + 2H_2O + O_2 = 2Fe^{+2} + 4OH^-$

The process results in a positively charged iron surface that sorbs the arsenate species by electrostatic interactions. In systems where dissolved sulfate is reduced to sulfide by sulfate-reducing bacteria, arsenic may be removed by the precipitation of insoluble arsenic sulfide (As_2S3) or co-precipitated with iron sulfides (FeS) (EPA, 2002).

ZVI has been used successfully to treat arsenic at several full scale superfund sites showing the reduction of arsenic concentrations to as low as 0.2 µg/L (EPA, 2002). The degree of arsenic contamination is dependent upon the contact time of groundwater with the reactive wall material. This contact time is a key design consideration based on aquifer characteristics such as flow and wall thickness. In addition, other competing constituents in groundwater such as total organic carbon may reduce the overall effectiveness of the ZVI and there is a potential for fouling. A pre-design investigation would be required to thoroughly characterize the site geochemistry and assess the performance of ZVI in the site-specific environment.

The current state of PRB technology does not provide a reactive media that can successfully remediate groundwater contaminated with benzene and toluene. These compounds would pass through a ZVI PRB without little or no degradation, but will not compromise the barrier's ability to treat other contaminants that are present. However, under GW-4, the organic compounds will be addressed within their respective source areas using other technologies as discussed above.

Groundwater Monitoring and Performance Evaluation with Institutional Controls

As with any groundwater treatment system, a periodic monitoring program would be required to evaluate the performance of the remedy. Groundwater sampling for the PRB would likely take the form of quarterly samples collected from a series of groundwater wells both upgradient and downgradient of the PRB. As discussed above, Alternative GW-4 would not decrease site-wide concentrations of arsenic in groundwater to levels within the target risk range due to the widespread presence of metals and organics at the Industri-Plex Site. This alternative provides protection of human health by preventing or controlling potential exposures to contaminated groundwater through institutional controls. Groundwater monitoring would be conducted on a periodic basis to provide the regulatory agencies with the appropriate data to determine whether additional actions are needed.

3.4 Development of Remedial Alternatives for Sediment

This section provides descriptions of remedial alternatives that would address areas where human health risks and hazards in excess of risk management criteria were identified based on potential current and future exposures to sediment and areas where unacceptable ecological risks were noted. The sediment areas with unacceptable risks include the following: HBHA Pond sediments (HBHA Pond) just south of the Industri-plex Site; Near Shore sediments (NS) along the Wells G&H Wetland at sediment sampling stations WH and NT-3 (east side of wetlands near former production well H) and stations 13/TT-27 (west side of wetlands near the railroad tracks), and along the west-central portion of the Cranberry Bog Conservation Area at sediment sampling station CB-03; and Deep Sediments (DS) along the HBHA Wetlands and the Wells G&H Wetlands. The remedial alternatives for these sediments were developed from the technologies and process options that were retained in Section 2.4.3.3 of the FS. The descriptions presented below provide a general description of the remedial alternatives that are considered for sediment. The screening of remedial alternatives for sediment is presented in Section 3.6.3.

3.4.1 Sediment Alternative 1: No Action

The No Action alternative was developed as a baseline case, as required by the NCP, to which all other alternatives may be compared. Under this alternative, it is assumed that no action would be taken to reduce the toxicity, mobility, or volume of contaminated sediment at any of the sediment locations where human health or ecological risks were identified.

The No Action alternative would not be effective at achieving the human health or environmental RAOs for sediment since it would not limit potential human or ecological exposures to contaminated sediment, either currently or in the future. There would be no treatment, containment, or removal of sediment that is contaminated with arsenic and other inorganic contaminants-of-concern, and future risks to human or ecological receptors would not be reduced or eliminated. This alternative would require a review of site conditions and risks every 5 years since contamination would remain on site above levels that allow for unlimited use and unrestricted exposure.

3.4.2 Sediment Alternative 2: Institutional Controls

Sediment Alternative 2 was developed as an alternative that does not involve treatment or removal, but provides protection of human health by preventing or controlling potential exposures to contaminated sediment through institutional controls. This alternative would only apply to sediment areas estimated to result in human health risks and hazards in excess of risk management criteria, specifically the near shore (NS) sediments in the Wells G&H wetland and Cranberry Bog Conservation Area, and the deeper sediment (DS) sample locations (sediment core sample areas) in the interior portions of the HBHA wetland and the Wells G&H wetland. This alternative would not reduce unacceptable ecological risks and therefore would not be suitable for the HBHA Pond sediments.

Under this alternative, institutional controls would be implemented to prevent future exposures to contaminated sediment in the vicinity of sampling stations where potential human health risks and hazards above risk management criteria were identified. Institutional controls would take the form of prohibitions on dredging or excavation in the interior wetland area unless adequate precautions (e.g. engineering controls, PPE) were taken to minimize or prevent direct contact with contaminated sediment during removal activities. These types of controls would be designed to address the potential human health risks and hazards that were identified under the future dredger scenarios for the HBHA and Wells G&H wetlands.

Institutional controls might also include the installation of a permanent barrier (i.e. chain link fence) to prevent human access to contaminated accessible (i.e., shoreline) areas. By preventing access to contaminated accessible sediment, these types of controls might be an effective way to mitigate potential human health risks and hazards from recreational contact with contamination.

Sediment Alternative 2 does not involve any actions that will reduce the toxicity, mobility, or volume of contamination in sediment. The only on-site activities that would be conducted under this alternative are constructing a fence enclosure around the impacted sediment areas and periodically reviewing site conditions and risks. As required by CERCLA, a review of site conditions and risks would be conducted every 5 years.

3.4.3 Sediment Alternative 3: Monitoring with Institutional Controls

Sediment Alternative 3 would be identical to Alternative 2 except that environmental monitoring would be included. Semi-annual groundwater, surface water, and sediment samples would be collected from the impacted areas to evaluate contaminant status and migration trends. As required by CERCLA, a review of site conditions and risks would be conducted every 5 years.

3.4.4 Sediment Alternative 4: Subaqueous Permeable Cap

Sediment Alternative 4 includes the placement of a subaqueous covering or cap of clean material over contaminated sediment that remains in place. Sediment that is not submerged would not be addressed by a subaqueous cap. Therefore, Sediment Alternative 4 is only applicable to the HBHA Pond sediments.

Sediment Alternative 4 must also include a source control element to eliminate potential continuing sources of contamination to sediment that might undermine the alternative and/or permit downstream migration of contamination. For the IP MSGRP Study Area, source control could take the form of groundwater intercept and treatment upgradient of the HBHA Pond to prevent continued discharges of contaminants into surface water and sediment. Source control actions will be addressed in subsequent sections as remedial alternatives for sediment and groundwater, and the implications of implementing combinations of alternatives to achieve RAOs will be discussed in Section 4.0.

3.4.4.1 Cap Construction

Subaqueous caps are generally constructed using granular material, such as clean sediment, sand, or gravel; but may also include geotextiles, liners, or other permeable elements. Layered subaqueous caps may also include a layer consisting of material that will attenuate the flux of contaminants, such as organic carbon, or some type of amendment that will increase the chemical or biological activity within the contaminated sediment zone.

While the materials to construct the cap varies, in general the objectives of the subaqueous cap are physical isolation of contaminated sediment, stabilization and erosion protection, and chemical isolation of contaminated sediment. Physical isolation of contaminated sediment from the aquatic environment is achieved by constructing a cap that is sufficiently thick to resist the forces of bioturbation and the ordinary disturbances that are present at the bottom of a surface water body. Sediment stabilization considerations for the design of a subaqueous cap include measures to prevent contaminated sediment resuspension and transport, and resistance to erosion from river or wave-induced currents. The chemical isolation component of a cap design involves an evaluation of the advective and diffusive processes that might occur within the cap, and the extent to which they might enable vertical transport of contaminants through the cap as groundwater discharges to sediment.

Several different equipment types and placement techniques may be used to install the subaqueous cover. The main objective of the placement technique will be to minimize bottom spread during cover placement so that contaminated sediment is not displaced and mobilized into the overlying surface water. To accomplish this goal, submerged discharge placement techniques are more appropriate than surface discharge techniques in areas where surface water depth is considerable. Several submerged discharge techniques are available for subaqueous cap placement, including submerged diffusers, which allows radial discharge of cover material at low velocity using a hydraulic pipeline or a gravity-fed tremie, consisting of a large-diameter conduit through which cover material can be placed. In shallow water sediment areas that will be covered, placement using traditional mechanical techniques (i.e. excavation, clamshell dredge) could be used. Monitoring sediment resuspension and contaminant releases during cap placement would be necessary. A silt curtain or silt screen could be used to prevent downstream migration of sediment that is mobilized by the cover placement process.

Submerged discharge and subaqueous mechanical placement techniques are appropriate where submerged sediment is sufficiently stable to allow placement without excessive sediment displacement into the overlying water column. The sediment in the HBHA Pond has very low specific gravity, and based on observations of its characteristics at the bottom of the Pond, submerged placement of a subaqueous cap is not likely to be feasible. Another method, which would be more suitable to cover sediments of this type would be to temporarily dewater the pond so that the cap materials can be placed without the risk of re-suspension and downstream migration of contaminated sediments.

The required thickness of the subaqueous cover would need to be determined during the design phase of the project, but typically 1 to 3 feet of clean material has been used in previous projects where geosynthetics were not used. The thickness of the cover must be adequate to chemically and biologically isolate the contaminated sediment from the aquatic environment that will inhabit the waterway after placement of the cover. The types of variables that will impact the design thickness of the cover include the physical and chemical properties of the contaminated and cover materials, the potential for bioturbation of the cover by aquatic organisms, and the potential for consolidation and erosion of the cover material. Laboratory tests have been developed to determine the thickness of a cover that is required to chemically isolate contaminants from the overlying water column. These tests may be performed in the presence of bioturbating organisms so that the impact of the combination of these factors can be assessed. Other physical factors that must be taken into consideration during the design process include loss of flood storage and potential loss of open water habitat. Both of these factors would require mitigations if the cap design results in impacts.

3.4.4.2 Operation, Maintenance, and Monitoring

Sediment Alternative 4 would also involve a long-term maintenance and performance monitoring program. The objectives of the program would be to mitigate erosional impacts to the cover that might reduce its thickness, to ensure the installed cap remains effective at eliminating exposures to underlying sediments, and to monitor the recovery of biota and re-colonization of the cap surface by aquatic organisms. The techniques that would be used to achieve these objectives include regular surface water, sediment and groundwater monitoring, periodic topographical surveys of the sediment surface and comparison to an as-built survey, the collection of surface water samples from the water column overlying the subaqueous cover, and chemical and biological monitoring of the cap materials. As required by CERCLA, a formal review of cap conditions and site risks would be conducted every five years to re-evaluate the protectiveness of the remedy.

3.4.5 Sediment Alternative 5: Stormwater Bypass, Sediment Retention with Partial Dredging and Create an Alternate Habitat

Sediment Alternative 5 was developed as a way to achieve the RAOs by reducing, to the extent practicable, the migration of soluble and particulate arsenic during storm events from the HBHA Pond to downstream depositional areas and by providing an alternate habitat for impacted benthic invertebrates at the HBHA Pond. This alternative only applies to the HBHA Pond sediments. The alternative objectives would be achieved by the implementation of four major components: 1) construction of a storm water bypass from Halls Brook, 2) construction of a sediment retention area within the northern section of the HBHA Pond, 3) dredging and restoration of contaminated sediments in the southern portion of the HBHA Pond, and 4) creating an alternate habitat to mitigate the loss of benthic habitat caused by the construction of the sediment retention area in the northern portion of the HBHA Pond.

Sediment Alternative 5 uses engineering controls to prevent storm flow conditions from impacting the HBHA Pond, thereby preventing the resuspension and mobilization of contaminated sediment from the Pond to the downstream portions of the Study Area. At present, the HBHA Pond receives influent flow from various sources including Halls Brook, the Atlantic Avenue Drainway, a secondary intermittent storm drainage tributary and groundwater discharge from the Industri-plex Site. According to stream flow data that was collected in 2001 and 2002 from the HBHA Pond outlet, the average flow leaving the HBHA Pond from the outlet at the southern end of the pond was 4.21 cubic feet per second (cfs). During this same time period, measurements of stream flows during storm events indicated flow rates up to 9.63 cfs (TtNUS, 2005). The major contributor to the increase in flows was from Halls Brook. The total arsenic concentrations discharging from the HBHA Pond were greatest during storm flow conditions due to an increase in suspended sediment transport during storm events which resulted in an overall increase in the particulate arsenic concentration.

In addition, as discussed in greater detail in the MSGRP RI, the primary source of arsenic contamination in the HBHA Pond is from groundwater discharges in the northern portion of the pond. Other potential sources include possible erosion of soils from the area between the Boston Edison right-of-way and the northern end of the HBHA Pond and from stream sediments originating from the New Boston Street Drainway. There is a chemocline in the HBHA Pond that is induced by the difference in specific conductance between oxic surface water provided by Halls Brook and the anoxic contaminated groundwater, and steady inputs of oxygen, iron, sulfates, and organic carbon. This chemocline is critical to sustaining geochemical reactions that are sequestering arsenic within the pond sediments. However, sudden increases in flows, as seen during storm conditions, mix the water column and break down the chemocline thus allowing more arsenic to be “flushed” downstream. In short, baseflow inputs of surface water from Halls Brook are necessary to effectively sequester arsenic within the northern portions of the HBHA Pond while flows associated with storm events break down the chemocline and allow increased discharges of arsenic from the pond to downstream areas.

3.4.5.1 Storm Water Bypass

A storm water bypass system would be constructed under this alternative to allow baseflow contributions of surface water from Halls Brook to continue to discharge to the newly created sediment retention area in the northern portion of the HBHA Pond, while diverting storm flow from Halls Brook to the southern portion of the HBHA Pond, away form the sediment retention area. This would be accomplished through the installation of a storm water diversion structure at the location where Halls Brook (which contributes more than half of the total flow entering the pond) flows into the HBHA Pond. This storm water diversion structure would consist of a weir designed to limit the flow of water entering the HBHA Pond from Halls Brook during storm events. Stormwater that accumulates behind the weir would be diverted to a storm water bypass discharge structure, which would discharge storm flow from Halls Brook downstream of a low-head cofferdam (see Sediment Retention Area below).

3.4.5.2 Sediment Retention Area at Northern Portion of the HBHA Pond

Under Sediment Alternative 5, the HBHA Pond would be laterally divided into three sections at a point immediately downstream of the mouth of Halls Brook by a combination of two low-head cofferdams constructed of driven inter-locked sheet piling. The primary low-head cofferdam would serve to reduce flows and encourage sedimentation within the northern portion of the HBHA Pond. Sedimentation in the northern portion would also be enhanced by flow diversions and silt curtains.

Studies have shown that arsenic could be controlled within the northern portion of the pond where contaminated groundwater is principally discharging. Sediment Alternative 5 features a sediment retention system that would be designed to decrease the migration of soluble and particulate arsenic through sediment resuspension and downstream deposition. The sediment retention system would include several measures that, in combination, could achieve significant reductions in the rate of sediment resuspension during high flows and contain suspended sediment before it migrates downstream. This system would be most applicable to the HBHA Pond, where extensive research has indicated a pattern of sediment transport due to high volume storm flow events.

The first feature of the sediment retention system would include the stabilization of the various inlet channels that provide flow to the HBHA Pond. The Atlantic Avenue Drainway, New Boston Street Drainway, which flows into Halls Brook, and Halls Brook are the major influent sources to the HBHA Pond. The channels through which surface water enters the HBHA Pond would be stabilized with rip rap or through the construction headwalls to reduce erosion of the stream channels into the Pond.

A second measure of the sediment retention system that would be taken to reduce the resuspension of contaminated sediment in HBHA Pond is the use of flow diversion mechanisms to reduce flow velocity at these inlets and minimize the impacts to the chemocline. Flow deflection would be accomplished through the use of gabion walls, concrete berms, or earthen dams installed at the inlet of each drainway to direct influent surface water upstream in a manner that reduces its ability to retain suspended sediment.

Flow velocity mitigation would also be performed within the HBHA Pond under this alternative. At present, surface water in the HBHA Pond flows without physical obstruction toward the south and discharges into the Halls Brook Holding Area wetlands. Sediment Alternative 5 would involve the installation of velocity-reducing features within the HBHA Pond, which would act as the primary mechanism for the sediment retention characteristics of the alternative. Flow control in the HBHA Pond would be accomplished through the construction of baffles/flow deflectors or installation of floating silt curtains around which surface water flow would be directed, resulting in a lower flow velocities as surface water moves toward the southern end of the pond. By decreasing flow velocity in the HBHA Pond, the ability for sediment particles to remain suspended in surface water is reduced.

The most significant sediment retention feature included in this alternative would be the construction of a dual low-head cofferdam system starting at the approximate location of the mouth of the Halls Brook and continuing west across the HBHA Pond, generally dividing the pond into a northern and southern sections with the northern portion serving as the sediment retention and secondary polishing area. The cofferdams would be constructed of driven interlocking sheet piles, installed to an elevation of approximately 6 to 12 inches above the water elevation on the downstream side. The low-head cofferdams would retain water from the northern side and would allow surface water to pass over the top into the secondary cofferdam treatment area. The base of the cofferdam would be protected with either concrete or rip rap to serve as an energy dissipater to prevent erosion which could potentially undermine the sheet pile.

The objective of the low-head cofferdam would be to reduce surface water flows - especially from storm events, maintain the chemocline, and allow the sedimentation of suspended solids within the northern portion of the HBHA Pond (sediment retention area). As flow velocity is reduced when surface water flow approaches the dam, sediment will begin to settle out of the water column and accumulate at the base of the dam or other quiescent portions of the pond (e.g. at silt curtain areas), as well as diffusion from accumulated sediments and subsequent chemocline precipitation. The cofferdam would be constructed in a manner that would enable temporary storage of a considerable volume of sediment equal to approximately 2,000 cubic yards of in-place sediment per vertical foot. Periodically, the sediment retention area would require dredging in order to maintain sufficient water depth to sustain the chemocline.

The secondary cofferdam would be constructed similar to the primary cofferdam using interlocked sheet piling. This secondary area would serve as a polishing treatment zone using aeration to further encourage precipitation of dissolved arsenic and would further improve water quality by increasing dissolved oxygen. This secondary cofferdam area would also serve as a backup or buffer in the event high flows or unforeseen circumstances cause excessive arsenic loading to pass through the first cofferdam. Periodically, the secondary sediment retention area may also require dredging.

3.4.5.3 Partial Dredging and Restoration at Southern Portion of the HBHA Pond

This alternative also requires that contaminated sediments in the southern portion of the HBHA Pond, which would be downstream of the low-head cofferdam, be dredged and restored to prevent further re-suspension and migration and protect aquatic life/ benthic invertebrates. Studies conducted by EPA indicate that the contaminated sediments in southern portion of the pond are the result of dissolution and migration of contaminated sediments from upstream sources rather than from direct groundwater discharges. Specific details about dredging activities and the handling, processing, and offsite disposal of contaminated sediment are discussed in Sediment Alternative 6 in the following section with the exception that the dredging for Alternative 5 only applies to the southern portion of the pond (i.e. downstream of the northernmost low-head cofferdam).

3.4.5.4 Providing and Alternate Habitat

To mitigate the loss of wetland habitat resulting from the creation of the sediment retention area in the northern portion of the HBHA Pond, a compensatory wetland would be constructed at a suitable location within the watershed. A wetland survey would be performed in reference background areas to characterize species and population inventories of similar habitats within the watershed. This survey would serve as the design basis for the created wetland. The wetland would be representative of the habitat lost including replacement of flora and fauna. Once designed, the wetland would be constructed. Periodic monitoring and maintenance of the wetland would also be required to remove invasive species during the period that the wetland plants become established and to monitor the re-population of aquatic organism.

If properly designed and constructed, Sediment Alternative 5 could achieve all RAOs for the Southern Portion of HBHA Pond and may assist in the achievement of RAOs for areas located downstream by reducing the continuing source of sediment contamination that is impacting the downstream portions of the Site.

3.4.5.5 Operations, Maintenance, and Monitoring

Sediment Alternative 5 would also involve a long-term maintenance and performance monitoring program. The primary objective of the program would be to mitigate sedimentation impacts within the northern portion of the HBHA Pond that, due to the low-head cofferdam and diversion of storm water flow, would eventually accumulate sediments thus reducing the pond depth to an extent that the pond may no longer be able to sustain the chemocline. The techniques that would be used to achieve these objectives include regular surface water monitoring of the chemocline/retention pond, periodic bathymetric surveys of the sediment surface and comparison to an as-built survey, and periodic dredging to maintain the as-built conditions.

Also, periodic surface water and sediment monitoring would be performed downstream of the low-head cofferdam to evaluate performance of the alternative, as well as periodic groundwater monitoring (upgradient and downgradient of the cofferdam). As required by CERCLA, a formal review of the pond and dam conditions and site risks would be conducted every five years to re-evaluate the protectiveness of the remedy.

3.4.6 Sediment Alternative 6: Removal and Off-Site Disposal

Sediment Alternative 6 features the removal (through mechanical excavation or hydraulic dredging) and off-site disposal of contaminated sediment. Excavated/dredged material would be transported and disposed at an off-site disposal facility. Sediment Alternative 6 would eliminate exposure routes to human and ecological receptors by removing contaminated sediment from one or all of the impacted areas.

Similar to other sediment alternatives, Sediment Alternative 6 must also include a source control element to eliminate potential continuing sources of contamination to sediment that might undermine the alternative and/or downstream migration. For the IP MSGRP Study Area, source control could take the form of groundwater intercept and treatment upgradient of the HBHA Pond to prevent continued discharges of contaminants into surface water and sediment. Source control actions will be addressed in subsequent sections as remedial alternatives for sediment and groundwater, and the implications of implementing combinations of alternatives to achieve RAOs will be discussed in Section 4.0.

3.4.6.1 Site Preparation

As mobilization of personnel, equipment, and materials to the Site commences, site preparation activities would be implemented to prepare for the subsequent excavation/dredging activities. Clearing and grubbing of site vegetation and obstructions would be performed to facilitate access to work areas, where necessary. Brush and trees would be cleared, chipped, and stockpiled at an on-site location for subsequent use as mulch or ground cover.

Haul roads would be constructed where necessary to facilitate access to the removal areas for dredging equipment and trucks. Sediment staging areas would be constructed so that dredged material could be temporarily stored prior to pre-treatment or disposal without impacting the environment. Silt fence, silt screen, or another containment system would be established during site preparation so that sediment that is resuspended during removal does not migrate. Sheet piles, cofferdams, or earthen dams might be constructed prior to excavation where localized dewatering would be beneficial to the sediment removal process.

Decontamination facilities, such as those described in Section 3.2.3.1, would be constructed adjacent to the sediment removal areas to prevent the transport of contaminated sediment onto dry land or roadways.

3.4.6.2 Sediment Removal

The sediment removal effort would encompass the entire HBHA Pond where concentrations of arsenic or other contaminants were detected at levels that pose unacceptable ecological risks and exceed the established PRGs. The sediment removal effort would also include the deeper sediment (DS) areas surrounding sediment core locations SC02, SC05, SC06, and SC08, and near shore (NS) sediment areas within the Wells G&H wetland and Cranberry Bog Conservation Area, which were associated with human health risks and hazards above risk management criteria. These locations are depicted on Figures 2-5a through 2-5d.

A preliminary removal area would be established around the sediment samples that exceeded the PRG and continued to the next sample location that exhibited arsenic concentrations below the PRG. Sediment removal would be conducted using the appropriate removal technology.

Areas of contaminated sediment that are accessible to conventional excavation equipment and that are not submerged beneath more than 1 foot of water (or can be easily dewatered to enable excavation of a “dry” sediment surface) will be excavated using a track-mounted hydraulic excavator. Areas of deeper submerged sediment would be removed using hydraulic dredging equipment. Sediment would be staged on site to be dewatered, loaded into trucks, transported to a central stockpile area, and eventually shipped off site for treatment (if necessary to comply with disposal regulations) and disposal.

3.4.6.3 Site Restoration and Wetlands Mitigation

Prior to the commencement of any construction activities, a wetland survey would be performed to document the existing conditions of the wetland and proposed locations of haul roads, equipment laydown areas or other support areas. All wetland areas impacted by construction activities would be reestablished to pre-construction conditions. Wetland areas impacted by dredging and sediment removal would be restored to match the surrounding wetland habitats including sediment substrate composition and plant species, with the exception of areas dominated by invasive species. In these locations, wetland restoration would attempt to improve wetland habitat and promote the development of an improved wetland plant community.

3.4.6.4 Waste Characterization and Off-Site Disposal

Excavated or dredged sediment would be transported to a dewatering area where free liquids would be allowed to drain to a collection point. This water would be collected and analyzed to evaluate onsite and offsite disposal options. The sediment may also require additional stabilization (e.g. solidification) to meet disposal requirements. The stockpiled sediment would ultimately be transported to an off-site disposal facility. Based on the anticipated concentration of arsenic in sediment that will be removed, it is assumed that excavated material will be suitable for disposal at a Subtitle C solid waste landfill. In order to confirm the appropriate disposal requirements for excavated sediment, waste characterization samples (as required by the disposal facility) will be collected from stockpiled dewatered sediment. Sediment would be transported to out-of-town treatment and/or disposal facilities using dump trailers with an approximate 20 cubic yard capacity (80,000 pound gross vehicle weight).

3.4.7 Sediment Alternative 7: Removal, Treatment, and On-Site Reuse

Sediment Alternative 7 is similar to Sediment Alternative 6 in that contaminated sediment in the areas identified as associated with human health risks and hazards or ecological risks would be excavated or dredged to the extent that the remaining material meets all of the PRGs. The only difference between the two alternatives is the treatment of excavated or dredged material once it is removed from the wetland. Sediment Alternative 7 would employ a treatment process (acid extraction) designed to remove arsenic from sediments by mixing it in a batch reactor with acids as described in Soil Alternative 5 above.

Sediment treatment would occur at a specially designed and constructed treatment area that would be sited within the boundaries of the study area. A description of the treatment process is provided in Section 3.2.5.2 of this FS. The primary difference between the treatment of sediment versus the treatment of soil is the degree of pre-treatment that is required in order to effectively handle the material. Contaminated sediment must be adequately dewatered prior to handling and treatment. Once treated, the sediments will have less organic material and could be re-used as wetland backfill, but would be most suitable for the lower substrate layers.

Similar to other sediment alternatives, Sediment Alternative 7 must also include a source control element to eliminate potential continuing sources of contamination to sediment that might undermine the alternative and/or downstream migration. For the IP MSGRP Study Area, source control could take the form of groundwater intercept and treatment upgradient of the HBHA Pond to prevent continued discharges of contaminants into surface water and sediment. Source control actions will be addressed in subsequent sections as remedial alternatives for sediment and groundwater, and the implications of implementing combinations of alternatives to achieve RAOs will be discussed in Section 4.0, when site-wide remedial strategies will be evaluated.

3.5 <u>Development of Remedial Alternatives for Surface Water</u>

This section provides descriptions of remedial alternatives that would address areas where there are unacceptable ecological risks to aquatic organisms exposed to elevated concentrations of arsenic and benzene in deeper portions of the HBHA Pond surface water resulting from contaminated groundwater discharges. No human health risks or hazards were identified as a result of exposure to surface water. However, surface water has been shown to be the principal transport mechanism for both soluble and particulate forms of arsenic associated with suspended solids and migration to downstream depositional areas. These alternatives were developed from the technologies and process options that were retained in Section 2.4.3.4. The descriptions presented below provide a general description of the remedial alternatives that are considered for surface water. The screening of remedial alternatives for surface water is presented in Section 3.6.4.

3.5.1 Surface Water Alternative 1: No Action

The No Action alternative was developed as a baseline case, as required by the NCP, to which all other alternatives may be compared. Under this alternative, it is assumed that no action would be taken to reduce the toxicity, migration, or volume of contaminated surface water within the deeper portions of the HBHA Pond where unacceptable ecological risks were identified due to arsenic and benzene contamination.

The No Action alternative would not be effective at achieving the environmental RAOs for surface water since it would not limit potential exposures of aquatic organisms to contaminated surface water, either currently or in the future. There would be no treatment, containment, or removal of the surface water that is contaminated with arsenic and benzene and future risks to ecological receptors would not be eliminated. This alternative would require a review of site conditions and risks every 5 years since contamination would remain on site above levels that allow for unlimited use and unrestricted exposure.

3.5.2 Surface Water Alternative 2: Monitoring

Surface Water Alternative 2 was developed as a limited action alternative that involves no active treatment. Monitoring would be conducted on a periodic basis to provide the regulatory agencies with the appropriate data to determine whether additional actions are needed. The activities that would be conducted under this alternative include: long-term monitoring of groundwater, surface water, sediments and evaluation of the impacts to the benthic community through toxicity tests to evaluate contaminant status and ecological impacts; and a review of site conditions and risks every 5 years.

3.5.3 Surface Water Alternative 3: Monitoring and Providing Alternate Habitat

Surface Water Alternative 3 is a limited action alternative that is identical to Alternative 2 except that it includes provisions for the development of an alternate habitat to compensate for the impacted portions of the HBHA Pond. This alternative would involve no active treatment except what may naturally occur through the chemical and biodegradation processes that may eventually reduce the source of organic groundwater, although inorganic groundwater contamination would persist, and provides for mitigation of lost wetland habitat by the construction of an alternate wetland habitat. The activities that would be conducted under this alternative include: long-term monitoring of groundwater, surface water, and sediments to evaluate contaminant status and migration; construction of a comparable wetland and a review of site conditions and risks every 5 years.

Surface Water Alternative 3 would involve long-term monitoring of environmental media and periodic reviews of site conditions and risks. Regular groundwater, surface water, and sediment samples would be collected to evaluate contaminant status and migration trends. As required by CERCLA, a formal review of site conditions and risks would be conducted every 5 years since contamination would remain on-site above levels which allow for unrestricted use and unlimited exposure.

Naturally occurring processes that reduce the concentrations of organics can extend for a very long time. In order to compensate for the loss of the aquatic habitat during this time, a similar wetland would be constructed. A wetland survey would be performed in reference background areas to characterize species and population inventories of similar habitats within the watershed. This survey would serve as the design basis for the created wetland. Once designed, the wetland would be constructed. More intensive monitoring would be required during the first few years as the wetland vegetation and benthic invertebrate communities become established.

Alternative 3 would not in itself minimize exposure or impacts to deep contaminated surface water in the HBHA Pond, but would attempt to offset those impacts by providing an alternate habitat in order to maintain a similar benthic community inventory for the watershed.

Monitoring would be conducted on a periodic basis to provide the regulatory agencies with the appropriate data to determine whether additional actions are needed and to evaluate the overall health and progress in establishing the created wetland. Since the progress of contaminant reduction would be slow, short-term impacts of contamination to surface water bodies at the HBHA Pond would be virtually unchanged from current conditions.

3.6 Screening of Remedial Alternatives

This section presents the screening of remedial alternatives for soil, groundwater, and sediment. The alternatives screening was conducted in accordance with the *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, October 1988). The purpose of the alternatives screening is to further refine the list of potential alternatives prior to performing the detailed analyses and to help tailor the detailed analysis of alternatives to the areas that must be addressed by the FS.

The EPA guidance expresses a preference for preserving the range of treatment and containment technologies that are initially developed although, this is not necessary if all alternatives in a portion of the range do not represent distinct viable alternatives. The alternative screening conducted below retains containment and treatment alternatives for the detailed analysis to the extent that their technical implementability is reasonable to address threats in a specific medium or area of the site.

Tables 3-1, 3-2, 3-3, and 3-4 present the screening of remedial alternatives for soil, groundwater, sediment, and surface water respectively. The results of the alternative screening are summarized briefly by medium below, and the alternatives that were retained for the detailed analyses are presented.

3.6.1 Screening of Remedial Alternatives for Soil

Table 3-1 presents the screening of soil remedial alternatives. This evaluation considers the effectiveness, implementability, and cost of implementing each alternative to address human health risks and hazards associated with arsenic contamination in soil. The two receptor/exposure scenarios that must be addressed by soil remedial actions for the FS include future exposure by a day care child with surface and subsurface soils and future exposure by an excavation worker to subsurface soils, both within the former Mishawum Lake bed area.

Effectiveness

Each of the soil alternatives (other than No Action) was considered effective at protecting human health in the long term. Long-term protection of human health would be achieved by Alternative 2 (Monitoring and Institutional Controls) through the imposition of restrictions on activities within the risk areas (Figures 2-3a and 2-3b) that might enable future exposures to contaminants in soil. Alternative 3 (Permeable Cover with Institutional Controls) would offer a slightly greater level of protection by removing 1.5 feet of surface soil and placing a permeable cover over contaminated areas. However, since contaminated soil with concentrations of arsenic exceeding remediation goals would be left in place, institutional controls such as those required for Alternative 2 would still be necessary to ensure long-term protection of human health.

Soil Alternative 4 (Excavation and Off-Site Disposal) and Alternative 5 (Excavation, Treatment, and On-Site Reuse) would achieve remediation goals by removing the entire volume of soil with concentrations of arsenic that exceed its remediation goal and replacing it with soil that meets the remediation goals. As such, each of these alternatives would be protective of human health in the long term.

The five soil alternatives were also evaluated based on their ability to protect human health and the environment in the short term. Short-term effectiveness is defined as the ability of an alternative to prevent impacts to human health and the environment during the construction and implementation phase. The No Action alternative and Monitoring with Institutional Controls were evaluated to be very effective in the short term, since no on-site construction would be required for their implementation. Permeable Cover with Institutional Controls would involve the excavation of soil throughout a large area, but to a shallow (1.5 feet below ground surface) depth. Conventional engineering controls such as dust control, equipment decontamination, and personal protective equipment could be used to mitigate any potential short-term exposures to contaminants by workers or the community so that the short-term effectiveness of this alternative would be very high.

Soil Alternatives 4 and 5 involve more extensive excavation activities over a much larger area and to a greater depth than Soil Alternative 3. For this reason, the potential for short-term impacts to human health are greater. Engineering controls would be utilized to minimize releases of contamination that might impact workers or the community, but the large volume of contaminated soil that would need to be handled to implement these alternatives would provide sufficient risk to short-term impacts that the short-term effectiveness was determined to be moderate.

Implementability

The implementability criteria that were evaluated in the alternatives screening included technical feasibility and administrative feasibility. The technical feasibility evaluation includes an assessment of the ability to construct, reliably operate, and meet technology-specific regulations for process options until the remedial action is complete. This evaluation also includes as assessment of the operations and maintenance of the alternative. Administrative feasibility refers to obtain approvals from other offices or agencies, and the availability of treatment, storage, and disposal facilities that would be required for the alternative.

For both surface and subsurface soils, Monitoring with Institutional Controls was considered easily implementable and very likely to reliably meet RAOs. The Permeable Cover with Institutional Controls, while also likely to meet RAOs, was determined to be much more difficult to construct because of the short-term impacts that would be encountered during construction in a developed area occupied by several active businesses.

The implementability evaluation for Soil Alternatives 4 and 5 was considerably different for surface soil than for subsurface soil, due mostly to the fact that surface soils are much more accessible to excavation equipment. Alternatives 4 and 5, which involve excavation of the entire volume of soil exceeding remediation goals, were considered to be very difficult to implement for surface soils and technically infeasible for subsurface soils based on the soil volumes and areas that would be impacted. To further complicate the implementability of these alternatives, the remediation area is heavily developed and commercialized such that excavations would involve the temporary relocation of an extensive network of underground utilities and would have significant short-term impacts on the local business community. Soil Alternatives 4 and 5 were retained for evaluation for surface soils to provide a cost comparison with Alternatives 1, 2, and 3 based on limited technical feasibility, but eliminated from consideration for subsurface soils based on technical infeasibility.

Cost

The cost evaluation that was performed for the alternatives screening included a qualitative analysis of relative costs between the five alternatives. Capital costs for No Action and Monitoring with Institutional Controls were considered to be low, since these alternatives would involve no on-site actions or very few actions. The Permeable Cover with Institutional Controls would involve moderate capital costs associated with the 1.5-foot interval excavation and off-site disposal of this soil at a RCRA hazardous waste landfill. Excavation and Off-Site Disposal and Excavation, Treatment, and On-Site Reuse were given high capital cost assessments based on the large volume of soil that would need to be excavated and either treated or disposed to achieve RAOs.

Relative operations and maintenance costs were considered high for Monitoring with Institutional Controls and Permeable Cover with Institutional Controls since soil with arsenic concentrations that exceed risk-based remediation goals would be left on site and periodic inspections and evaluations of the remedy's effectiveness would need to be made. Alternatives 4 and 5, which involve the complete removal of soil containing arsenic in excess of remediation goals, would incur low operations and maintenance costs.

3.6.2 Screening of Remedial Alternatives for Groundwater

Table 3-2 presents the screening of groundwater remedial alternatives. This evaluation considers the effectiveness, implementability, and cost of implementing each alternative to address human health risks and hazards and/or ecological risks associated with contaminated groundwater. The selection of groundwater remedial alternatives for the detailed analysis is summarized on Table 3-6.

Effectiveness

As stated in Sections 1.0 and 2.0, the treatment of Site-wide groundwater to achieve the preliminary remediation goals is considered technically infeasible and impractical.

Consequently, remedial alternatives for groundwater focus on the management of contaminant migration and the prevention of exposure rather than treatment to achieve remediation goals throughout the entire groundwater risk area. As such, the ability of each alternative (other than No Action) to protect human health in the long term would be dependent upon institutional controls placed on properties located within the contaminated groundwater plume to prohibit groundwater uses that might result in harmful exposures to contaminants. Therefore the ability of each alternative to protect human health in the long term was considered equivalent.

Although there were no unacceptable ecological risks due to exposures to Site groundwater, contaminated groundwater that is allowed to discharge to the HBHA Pond is known to contribute to ecological risks to benthic communities in the Pond due to exposure to contaminated surface water. Therefore, the evaluation of environmental protection considered the ability of the alternative to prevent contaminated groundwater discharges to the Pond. Alternative 2 (Pond Intercept with Institutional Controls) would permit untreated groundwater to discharge to the Pond, and was therefore determined to be less protective to the environment than Alternatives 3 and 4.

The short term effectiveness of the No Action alternative and Pond Intercept with Institutional Controls were evaluated to be very high since there would be no construction activities associated with their implementation. Alternative 3 (Plume Intercept by Groundwater Extraction, Treatment, and Discharge) and Alternative 4 (Plume Intercept by In-Situ Groundwater Treatment) were evaluated to be moderate to high in short-term effectiveness. While there would be little to no risk of exposure to contaminant by workers or the community during construction (these could be prevented using conventional engineering controls), they would involve relatively extensive construction activities during which subsurface soils and groundwater would become more accessible to human receptors.

Alternatives 3 and 4 would reduce the toxicity, mobility, and volume of contaminants in groundwater through traditional treatment methods, although contaminant levels would not be expected to reach remediation goals in the foreseeable future. Alternative 2 does not use treatment to reduce the toxicity, mobility, or volume of contaminants in groundwater, instead allowing them to migrate into the northern portion of the HBHA Pond.

Implementability

All of the groundwater alternatives were considered to be technically feasible (i.e. constructible), although there is some uncertainty as to the reliability of a permeable reactive barrier given the groundwater geochemistry at the Site. The reliability of Alternative 2 (Pond Intercept with Institutional Controls) during the operations and maintenance phase would be dependent upon implementation of a Pond remedy that includes sediment retention so that contaminants that discharge to the Pond are not mobilized to downstream depositional areas. All of the groundwater alternatives were determined to be feasible from an administrative standpoint.

Cost

Capital costs to implement each of the groundwater alternatives were evaluated qualitatively in comparison to the other groundwater alternatives. There would be no capital costs associate with the No Action alternative since no construction or legal costs would be incurred. Pond Intercept with Institutional Controls was evaluated to be low in cost relative to the other alternatives, since the only capital costs would be legal fees required to draft and implement institutional controls. Alternatives 3 and 4 would be relatively high in capital costs, since they would involve extensive construction, startup, and testing activities.

Operations and maintenance costs for Alternative 2 would be low relative to the other groundwater alternatives, consisting solely of periodic inspections to verify the effectiveness of institutional controls and a periodic groundwater monitoring program. Alternative 3 (Plume Intercept by Groundwater Extraction) would involve these same activities plus day-to-day operations and maintenance of the groundwater extraction system, an extensive process monitoring schedule that would involve high analytical costs, and repair/replacement costs for mechanical or electrical components that are required to operate the groundwater extraction system effectively. Operations and maintenance costs for Alternative 4 (Plume Intercept by In-Situ Treatment) would involve verification of institutional controls, groundwater monitoring, and in-situ treatment process monitoring; as well as potential treatment media changeout costs if the permeable reactive barrier reaches breakthrough and no longer retains sufficient binding sites to effectively treat groundwater.

3.6.3 Screening of Remedial Alternatives for Sediment

Table 3-3 presents the screening of remedial alternatives for sediment. This evaluation considers the effectiveness, implementability, and cost of implementing each of the seven sediment alternatives to address human health risks and hazards and/or ecological risks associated with contaminated sediments.

The screening and selection of sediment remedial alternatives for the detailed analysis was performed separately by receptor and geographical area so that remedial alternatives could be developed to specifically address each of the RAOs that were developed for sediment and so that alternatives could be developed that were appropriate for the setting where the sediments were located (i.e. shallow sediments near the shore of a wetland versus sediments at the bottom of a pond). This approach will enable the detailed analysis of remedial alternatives that are appropriate to address the range of exposure scenarios that were identified by the baseline risk assessments without evaluating remedial alternatives that are not practical to address risks in certain areas of the site.
Alternative screening and selection for detailed analysis addressed the RAOs that were developed for each of the following receptors and site areas:

- "Shoreline" sediment or "near shore" (NS) sediments that are accessible to future recreational receptors; the areas that will be addressed by these alternatives include sampling stations located within the Wells G&H Wetland (WH, 13/TT-27, NT-3) and Cranberry Bog Conservation Area (CB-03).

- Sediment cores or "deep sediments" (DS) that are accessible to future dredging workers; the areas that will be addressed by these alternatives include interior portions of the HBHA wetlands (SC02) and interior portions of the Wells G&H wetland (SC05, SC06, and SC08).

- HBHA Pond sediment (HBHA Pond); these alternatives will address ecological risks related to contamination in sediment within the HBHA Pond.

3.6.3.1 Screening of Alternatives for Near Shore Sediments (NS)

The alternatives that were evaluated to address risks identified from potential future exposures to near-shore sediments included No Action, Institutional Controls, Monitoring with Institutional Controls, Subaqueous Cap, Removal and Offsite Disposal, and Removal, Treatment and On-site Reuse. This section provides a summary of the alternatives screening evaluation for near-shore sediments.

Effectiveness

The effectiveness evaluation for near-shore sediments focused primary on long-term protection of human health, since future recreational users were the receptors for which unacceptable risks were identified. The No Action alternative would not be protective of human health in the long term, since no actions would be taken to prevent future exposures to contaminated near-shore sediment. Institutional Controls and Monitoring with Institutional Controls would provide human health protection through the use of deed restrictions or physical barriers to prevent activities that might result in future exposures to contaminated sediment. These alternatives were determined to provide moderate protection to human health due to the fact that contaminated sediments are located at the edge of the wetlands, in locations that are relatively easy to access, and the enforcement of institutional controls would be an uncertainty that might impact the long-term effectiveness of these alternatives.

The Subaqueous Cap was evaluated to be an ineffective alternative to address near-shore sediments. Much of the near-shore sediment areas that would be addressed by remedial actions are either located in shallow water or not submerged beneath surface water. The placement of a cap over these sediments would not only be impractical, but also would improve the accessibility to sediments in the interior portions of the wetlands, potentially creating additional human health risks. For these reasons, the subaqueous cap was not retained for consideration in the detailed analysis of near-shore sediment alternatives.

Removal and Off-Site Disposal and Removal, Treatment, and On-Site Reuse of sediment would protect human health in the long term through the removal of sediment with contaminants exceeding their remediation goal and replacement of this sediment with clean material (either from an off-site source or treated sediment). These alternatives would also include wetland re-creation in the areas impacted by the excavation, therefore providing a high level of long-term environmental protection despite the short-term impacts to the environment that would result from excavation of sediment in the wetland.

Short-term effectiveness of No Action, Institutional Controls, and Monitoring with Institutional Controls would be very high since no construction activities would be conducted, therefore there would be no potential for human health or environmental impacts. Removal and Off-Site Disposal and Removal, Treatment, and On-Site Reuse were rated moderate for short-term effectiveness, since excavation in the wetland would have heavy impacts on wetland areas and removal of contaminated sediment would create the potential for human contact with contaminants. Each of these alternatives would utilize engineering controls to prevent unacceptable short-term exposures that might impact the health of workers or the community, and wetland re-creation to mitigate the short-term environmental impacts that would be incurred during implementation.

No Action, Institutional Controls, and Monitoring with Institutional Controls would not achieve any reduction in the toxicity, mobility, or volume of contaminants through treatment. Removal and Off-Site Disposal would not reduce the toxicity, mobility, or volume of contaminants in sediment, but would include the treatment of dewatering liquids that are generated and would remove dissolved or suspended contaminants. Removal, Treatment, and On-Site Reuse would utilize a treatment technology to reduce the toxicity, mobility, and volume of contaminants in sediment in addition to treating dewatering effluent to remove contaminants.

Implementability

No Action, Institutional Controls, Monitoring with Institutional Controls, and Removal and Off-Site Disposal were evaluated to be technically feasible. Each of these alternatives (with the exception of No Action) was also determined to be potentially reliable to achieve RAOs during both the implementation and operations and maintenance phases of the remedial action. Removal, Treatment, and On-Site Reuse was screened out for near-shore sediments based on the uncertainty associated with the reliability of treatment methods to achieve remediation goals.

Cost

The No Action alternative would not incur any capital costs. Institutional Controls and Monitoring with Institutional Controls would require relatively low capital costs, consisting primarily of legal fees to draft and implement institutional controls and installation of chain-link fencing to prevent human access to contaminated areas. Capital costs for Removal and Off-Site Disposal would be high relative to the other alternatives that were retained for near-shore sediment due to the effort required to excavate and dewater sediment from a wetland area, and the cost to transport and dispose of contaminated sediments at an off-site disposal facility.

Operations and maintenance costs for Institutional Controls would be relatively low, consisting primarily of periodic inspections to verify the effectiveness of the controls and occasional repair of fencing. Monitoring and Institutional Controls would require moderate operations and maintenance costs due to the costs associated with implementing a periodic sampling program to evaluate sediment and surface water conditions in the remediation areas. Five-year reviews would be required for these alternatives since contamination would remain on-site above levels that would allow for unrestricted exposure to sediments.

Removal and Off-Site Disposal would require low operations and maintenance expenditures since all sediment with concentrations of contaminants that pose potential human health risks would be removed from near-shore sediments. The restoration of wetland areas that are impacted by near-shore sediment removal would require up to 2 years of maintenance to ensure that wetland plant species and wetland habitats are being adequately restored.

3.6.3.2 Screening of Alternatives for Deep Sediments (DS)

As with the near-shore sediments, only alternatives that were applicable to deep sediments were considered for the detailed analysis. No Action, Institutional Controls, Monitoring with Institutional Controls, Subaqueous Cap, Removal and Offsite Disposal, and Removal, Treatment and On-site Reuse were screened against the evaluation criteria for deep sediments. A summary of the screening of alternatives for deep sediments is presented below.

Effectiveness

The No Action alternative would not be protective of human health in the long term, since no actions would be taken to prevent future exposures by dredging workers to contaminated sediments in the Halls Brook Holding Area wetlands and Wells G&H Wetland.

Institutional Controls and Monitoring with Institutional Controls would provide human health protection through the use of deed restrictions to prevent dredging in the areas that might result in future exposures to contaminated sediment. These alternatives were determined to provide a high level of protection to human health due to the relative inaccessibility of the sediment core locations (at depth within the interior portions of wetland), exposure to which would require the use of dredging equipment.

The Subaqueous Cap was evaluated to be an ineffective alternative to address deep sediments, since it would not be an adequate deterrent to dredging equipment operating in the deep sediment risk areas. The relatively thin layer of clean sediment material that would be used to construct a subaqueous cap could easily be penetrated in the event that dredging equipment were to be utilized in these areas, therefore placement of this material would provide no additional protection to human health beyond that which would be achieved through restrictions or prevention of dredging activities. For this reason, the Subaqueous Cap alternative was not retained for the detailed analysis of alternative for deep sediments.

Removal and Off-Site Disposal and Removal, Treatment, and On-Site Reuse of sediment in deep sediment risk locations would protect human health in the long term through the removal of sediment with contaminants exceeding the remediation goals and replacement of this sediment with clean material (either from an off-site source or treated sediment). These alternatives would also include wetland re-creation in the areas impacted by the excavation, therefore providing a high level of long-term environmental protection despite the short-term impacts to the environment that would result from excavation of sediment in the wetland.

The evaluation of short-term effectiveness for the deep sediment alternatives indicated high short-term effectiveness for No Action, Institutional Controls, and Monitoring with Institutional Controls since no construction activities would be utilized and therefore there would be no potential for human health impacts to workers or the community. The alternatives that involve sediment removal would have significant short-term impacts due to the large area of sediment that would need to be addressed to achieve RAOs. Engineering controls would be used to prevent unacceptable exposures to contaminants by workers or the community and impacted wetland areas would be restored, but the area and volume of material that would be impacted by these alternatives would be considerable.

Implementability

As discussed previously in the screening of alternatives for near-shore sediment, the effectiveness of Removal, Treatment, and On-Site Reuse was determined to be limited for sediments based on the uncertainties associated with the reliability of treatment processes. Therefore, this alternative was not retained for the detailed analysis of alternatives for deep sediment.

Due to the large area that would be impacted by the removal of contaminated sediment in the deep sediment risk areas, the technical feasibility of Removal and Off-Site Disposal was evaluated to be very low. Much of these sediment risk areas are currently submerged beneath surface water, and a large-scale dewatering and surface water diversion effort would be necessary to remove them from the wetland. Furthermore, the availability of off-site disposal capacity for this volume of material (160,000 cubic yards) would be limited. Nevertheless, this alternative was retained for the detailed analysis to provide an active remediation alternative against which No Action and Institutional Controls could be compared from a cost and effectiveness standpoint.

No Action, Institutional Controls, and Monitoring with Institutional Controls were determined to be easily implementable in the deep sediment risk areas. Monitoring would involve extra effort over institutional controls alone. The value derived from monitoring was determined not to be sufficient to warrant its inclusion for the detailed analysis, therefore it was not retained.

Cost

There would be no capital costs associated with the No Action alternative. Capital costs to implement Institutional Controls in the deep sediment areas would be low in comparison to sediment removal. Sediment removal and off-site disposal would require very high capital expenditures.

Operations and maintenance costs for Institutional Controls would be low, consisting of periodic inspections to verify the effectiveness of the controls. Five-year reviews would be required under this alternative since contaminants would remain on the site above levels which would allow unrestricted exposure to sediments. Removal and Off-Site disposal of sediment would not require long-term operations and maintenance since all deep sediment with contaminants above risk-based remediation goals would be removed from the Site. The restoration of wetlands that are impacted by sediment removal would require up to two years of maintenance to ensure that wetland species and habitats are adequately established.

3.6.3.3 Screening of Alternatives for HBHA Pond Sediments (HBHA)

Applicable alternatives that were evaluated for the HBHA sediments included No Action, Institutional Controls, Monitoring with Institutional Controls, Subaqueous Cap, Stormwater Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat, Removal and Offsite Disposal, and Removal, Treatment and On-site Reuse. This section provides a summary of the alternatives screening evaluation.

Effectiveness

The effectiveness evaluation for the HBHA Pond focused primarily on the ability of alternatives to protect the environment, since the unacceptable risks identified with exposure to contaminated sediment in the Pond were associated with ecological receptors. The evaluation of human health protection for the HBHA Pond sediment alternatives assessed the ability of the alternative to prevent downstream migration of contaminated sediment that might create future human health risks.

It should be noted that the long-term effectiveness of alternatives for the HBHA Pond is, in most cases, dependent upon the implementation of a groundwater remedy that intercepts the groundwater contaminant plume prior to discharge to the Pond. If contaminated groundwater is allowed to discharge to the Pond, the subaqueous cap and sediment removal alternatives would not be effective in the long term since Pond sediments would ultimately be recontaminated by the continuing source of arsenic and benzene entering the Pond through groundwater discharge. Therefore, the protectiveness evaluation that is made in the alternative screening for these alternatives assumes that a plume intercept alternative would be implemented to prevent discharges of contaminants to the Pond.

No Action, Institutional Controls, and Monitoring with Institutional Controls were determined not to be protective of ecological receptors, since no actions would be taken to prevent ecological exposures to contaminated sediment. Since institutional controls would not be adequate to protect ecological receptors, they were not retained for HBHA Pond sediment alternatives. Instead, monitoring without institutional controls was retained for the detailed analysis. Monitoring without institutional controls would not be protective of human health or the environment in the long term.

A Subaqueous Cap would be protective of the environment (assuming a plume intercept alternative is implemented for groundwater) by providing a subaqueous barrier that would limit or prevent ecological exposures to contaminated sediment. The long-term effectiveness of this technology would be uncertain though, since stresses to the cap from surface water currents and bioturbation could result in excessive wear and potential failure. The Subaqueous Cap, by isolating contaminated sediment from the overlying water column, would protect human health by preventing resuspension and downstream migration of contaminated sediments from the Pond bottom.

The Stormwater Bypass with Sediment Retention alternative would protect ecological receptors in the portion of the Pond from which contaminated sediments are dredged. Ecological receptors would not be protected in the northern (sediment retention) portion of the Pond, where contaminated sediment would be left in place but prevented from migrating through the use of surface water controls. Long-term environmental protection would be provided by this alternative through the creation of an alternate habitat to compensate for the approximately one acre Pond habitat that would be lost. This alternative would provide long-term protection of human health through the removal of contaminated sediment in the southern portion of the Pond and through the construction of a sediment retention area in the northern portion of the Pond that would prevent sediment transport to downstream areas. This alternative would be effective in the long-term without a plume intercept alternative for groundwater, since contaminants that discharge to the Pond would be contained within the sediment retention portion of the HBHA Pond and periodically dredged.

The two alternatives that involve sediment removal from the entire Pond area (Removal and Off-Site Disposal and Removal, Treatment, and On-Site Reuse) would protect human health and the environment in the long term since all sediment with concentrations of arsenic in excess of the risk-based remediation goals would be removed from the Pond. These alternatives would not be effective in the long term without the implementation of a plume intercept alternative for groundwater.

Short-term effectiveness for the No Action and Monitoring alternatives would be very high since no construction activities would be required for their implementation. Short-term effectiveness of the Subaqueous Cap would be very low, since in order to install a cap over sediments at the Pond bottom it would need to be dewatered. While engineering controls would be utilized to minimize human health impacts from cap construction, the construction process would make contaminated material more accessible to workers and the community. The short-term environmental impacts of the Subaqueous Cap alternatives would be very high (effectiveness low) since the aquatic ecosystem at the Pond bottom would be essentially destroyed.

The short-term effectiveness of the Stormwater Bypass/Sediment Retention, Removal and Off-Site Disposal, and Removal, Treatment, and On-Site Reuse would be similar. Engineering controls would be used to prevent unacceptable exposures to contaminants by workers and the community, but the magnitude of construction activities that would be required would have significant short-term impacts to the environment including the destruction of aquatic ecosystems in the Pond.

No Action and Monitoring would not achieve any reduction in the toxicity, mobility, or volume of contaminants through treatment. Except for the treatment of sediment dewatering effluent, Subaqueous Cap and Removal and Off-Site Disposal would not reduce the toxicity, mobility, or volume of contaminants in sediment. Removal, Treatment, and On-Site Reuse would utilize a treatment technology to reduce the toxicity, mobility, and volume of contaminants in sediment in addition to treating dewatering effluent to remove contaminants.

Implementability

No Action and Monitoring would be easily implementable. The Subaqueous Cap would be very difficult to implement due to the nature of the sediment at the bottom of the Pond. Placement of the cap directly onto the Pond bottom without dewatering the Pond would be very difficult and time consuming, if not impossible. Pond sediments have very low percent solids, and would be displaced and mobilized very easily if cap materials were placed while still submerged. For this reason, it was assumed for evaluation of this alternative that is would require dewatering of the Pond and pumping influent water around the Pond during cap placement. Despite the construction difficulties associated with the alternative, it was retained for further evaluation in the detailed analysis of alternatives for the HBHA Pond.

Stormwater Bypass/Sediment Retention and Removal and Off-Site Disposal would be implementable and reliable to achieve the objectives of the alternative. As was stated for the evaluation of alternatives for near-shore sediment and deep sediments, treatment technologies for sediment containing arsenic are generally not sufficiently developed enough to be considered reliable, and Removal, Treatment, and On-Site Reuse was not retained for the detailed analysis of alternatives for the HBHA Pond sediments.

Cost

There would be no capital costs associated with the implement of No Action or Monitoring. Capital costs to construct a subaqueous cap would be moderate in comparison to the other sediment alternative for the Pond. Stormwater Bypass and Sediment Retention with an Alternate Habitat and Removal and Off-Site Disposal would require high capital expenditures.

Operations and maintenance costs for Monitoring would be low compared to the other HBHA Pond alternatives. The Subaqueous Cap would require high maintenance costs, including periodic underwater inspections to verify the integrity of the cap and bathymetric surveys to evaluate the degree of cap erosion or to identify potential weaknesses in the cap that might enable contaminants to penetrate the cap. Stormwater Bypass/Sediment Retention with Alternate Habitat would require moderate operations and maintenance costs including sediment/surface water monitoring, periodic inspections of the surface water flow controls, and periodic dredging of sediment that accumulates in the sediment retention area. There would be no operations and maintenance costs associated with Removal and Off-Site Disposal since all sediment with concentrations of arsenic that exceed the remediation goal would be removed from the Pond.

Since sediment contamination would remain at the Pond above levels which would enable unrestricted exposure to HBHA Pond sediments, each alternative (except Removal and Off-Site Disposal) would require 5-year reviews to evaluate the protectiveness of the remedy.

3.6.4 Screening of Remedial Alternatives for Surface Water

Table 3-4 presents the screening of surface water remedial alternatives. This evaluation considers the effectiveness, implementability, and cost of implementing each alternative to ecological risks associated with contaminated deep surface water of the HBHA Pond. Table 3-8 provides a summary of the alternatives that will be retained for the detailed analysis of alternatives for sediment.

As stated in Sections 1.0 and 2.0, the area of surface water that presents an unacceptable ecological risk is the deeper surface water of the HBHA Pond. This contaminated water is the result of the direct discharge of contaminated groundwater. As a result, removal options for surface water were not considered as they are not considered technically feasible or practical if contaminated groundwater is not addressed. Likewise, if contaminated groundwater is addressed, then the contaminated surface water would abate through natural attenuation processes. Alternatives considered for evaluation include No Action, Monitoring, and Monitoring and Providing an Alternate Habitat.

All alternatives are considered technically and administratively feasible. The alternative Monitoring and Providing an Alternate Habitat would be the most difficult to implement due to the difficulty in locating up to 5-acres of land within the watershed to create an alternate wetland habitat. Similarly, the alternative Monitoring and Providing an Alternate Habitat would also be the most expensive alternative to construct.

No alternative would provide any protection to the environment of the deep water within the HBHA Pond. Only the alternative Monitoring and Providing an Alternate Habitat would offer protection by creating an alternate habitat within the watershed to maintain the current inventory and diversity of benthic species and habitat.

All alternatives were retained for further detailed evaluation.

Effectiveness

No alternative would provide any protection to the environment within the HBHA Pond. Only the alternative Monitoring and Providing an Alternate Habitat would offer protection by creating an alternate habitat within the watershed to maintain the current inventory and diversity of benthic species and habitat.

Implementability

All alternatives are considered technically and administratively feasible. The alternative Monitoring and Providing an Alternate Habitat would be the most difficult to implement due to the difficulty in locating up to 5-acres of land within the watershed to create an alternate wetland habitat.

Cost

There would be no capital costs associated with No Action and Monitoring. The cost to implement Monitoring with an Alternate Habitat would be moderate in comparison to these other alternatives.

Operations and maintenance costs would below for monitoring only. The construction of a compensatory wetland that would be conducted under Monitoring with Providing Alternate Habitat would involve moderate maintenance costs associated with the cultivation of the created wetland and verification of its integrity.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

The remedial alternatives that were developed and screened in Section 3.0 are analyzed in detail in this section. The detailed analysis of alternatives provides information to facilitate selection of a specific remedy or combination of remedies. The detailed analysis of alternatives was developed in accordance with the NCP (40 CFR 200.430(e)) and the *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, Oct 1988).

4.1 Evaluation Criteria

In conformance with the NCP, seven of the following nine criteria were used to evaluate each of the retained alternatives during the detailed analysis. The last two criteria, state and community acceptance, will be addressed following the receipt of state and public comments on the RI/FS.

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume Through Treatment
- Short-Term Effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

Under the NCP, the selection of the remedy is based on the nine evaluation criteria, which are categorized into three groups:

- <u>Threshold Criteria</u> - The overall protection of human health and the environment, and compliance with ARARs are threshold criteria that each alternative must meet in order to be eligible for selection.

- Primary Balancing Criteria - The five primary balancing criteria are long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost.

- Modifying Criteria - The state and community acceptance are modifying criteria that will be considered in remedy selection.

Brief, general discussions of these evaluation criteria are presented in the following text. Detailed analyses of each alternative using the evaluation criteria are presented in Section 4.2. The comparative analysis of the remedial alternatives is presented in Section 4.3.

4.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides a final check to assess whether or not each alternative provides adequate protection of human health and the environment. The overall assessment of protection draws on the assessments conducted under other evaluation criteria including: long-term effectiveness and permanence, short-term effectiveness, and compliance with Applicable or Relevant and Appropriate Requirements (ARARs). The evaluation focuses on whether or not a specific alternative achieves adequate protection and how risks are eliminated, reduced, or controlled, and whether RAOs would be achieved.

4.1.2 Compliance with ARARs

ARARs are considered during the detailed evaluation of alternatives. Alternatives are assessed on whether or not they attain ARARs. When an ARAR cannot be met, the basis for justification of a waiver under CERCLA, or within the specific requirement, is presented. The actual determination of which ARARs are requirements is made by the EPA in consultation with the MADEP.

4.1.3 Long-Term Effectiveness and Permanence

Under this criterion, the alternatives are evaluated for long-term effectiveness, permanence, and the degree of risk remaining after the RAOs have been met. The following components are evaluated:

- Magnitude of residual risks - assesses the residual risk remaining from untreated wastes or treatment residuals at the conclusion of remedial actions, the remaining sources of risk, and the need for 5-year reviews.

- Adequacy and reliability of controls - assesses controls that are used to manage treatment residuals or remaining untreated wastes. This assessment includes addressing: the likelihood of technologies to meet required efficiencies or specifications, type and degree of long-term management, long-term monitoring requirements, operation and maintenance (O&M) functions to be performed, uncertainties associated with long-term O&M, potential need for replacement of technical components and associated magnitude of risks or threats, degree of confidence in controls to handle potential problems, and uncertainties associated with land disposal of untreated wastes and residuals.

4.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the statutory preference for remedies that employ treatment as a principal element by assessing the relative performance of different treatment technologies for reducing the toxicity, mobility, or volume of the contaminated media. Specifically, the analysis should examine the magnitude, significance, and irreversibility of the estimated reductions.

The degree to which remedial alternatives employ treatment that reduces toxicity, mobility, or volume is assessed by considering the following factors:

- The treatment processes that the remedies employ, the media they would treat, and threats addressed;
- The approximate amount of hazardous materials that would be destroyed or treated;
- The degree of expected reduction in toxicity, mobility, or volume as a result of treatment;
- The degree to which the treatment is irreversible;
- The type and quantity of residuals that would remain following treatment, considering the persistence, toxicity, mobility, and bioaccumulation capacity of the contaminants of concern and impacted media, and

- The ability of alternatives to satisfy the statutory preference for treatment as a principal element.

4.1.5 Short-Term Effectiveness

The assessment of short-term effectiveness during construction or implementation until the RAOs are met includes consideration of the following factors:

- Potential short-term impacts to the community during remedial actions and whether risks may be addressed or mitigated;
- Potential impacts to, and protection of, the workers during remedial actions;
- Potential adverse environmental impacts that result from construction and implementation of the alternative, and the reliability of mitigation measures, and
- Time until RAOs are achieved.

4.1.6 Implementability

The ease or difficulty of implementing a remedial alternative is assessed by considering the following factors during the detailed analysis:

- Technical Feasibility:
  - Degree of difficulty or uncertainties associated with constructing and operating the alternative;
  - Technical difficulties associated with the technologies' reliability that could result in schedule delays;
  - Likelihood of additional remedial actions and anticipated ease or difficulty in implementation, and
  - Ability to monitor the effectiveness of the remedy and risks of exposure if monitoring is insufficient to detect remedy failure.
- Administrative Feasibility:
  - The need to coordinate with other offices and agencies, and obtain necessary approvals and permits.

- Availability of Services and Materials:
  - Availability of adequate capacity and location of treatment, storage, and disposal services, if required;
  - Availability of necessary equipment and specialists;
  - Availability of treatment technologies comprising the alternative, sufficient demonstration of the technologies, and availability of vendors, and
  - Availability of services and materials, and the potential for obtaining competitive bids.

4.1.7 Cost

A detailed cost analysis is performed for each alternative to assess the net present worth cost to implement the remedial actions. The cost analysis consists of the following:

- Estimation of capital (direct and indirect) and annual O&M costs;
- Development of costs with an accuracy in the range of plus 50 percent to minus 30 percent, and
- Calculation of the present worth (capital and O&M costs) of the alternative by discounting to a base year or current year using a discount rate of seven percent.

4.1.8 State Acceptance

The MADEP is providing input to the feasibility study process on an ongoing basis and will continue to do so throughout the public comment period. Assessment of the state concerns may not be completed until comments on the RI/FS are received. As a result, this FS does not include any additional discussion about this criterion for any of the alternatives analyzed. State concerns may be discussed, to the extent possible, in the proposed plan to be issued for public comment. The state concerns that will be assessed include the following:

1) The state's position and key concerns related to the preferred alternative and other alternatives and,
2) State comments on ARARs or the proposed use of waivers.

4.1.9 Community Acceptance

This criterion refers to the community's comments on the remedial alternatives under consideration. The community is broadly defined to include all interested parties. Community concerns would be addressed after the public comment period, which follows the release of the RI/FS report. As a result, this FS does not include any additional discussion about this criterion for any of the alternatives analyzed.

4.2 Individual Analysis of Alternatives

The individual analysis of alternatives is presented on Tables 4-1 through 4-27. Each of the alternatives that were retained in Section 3.0 are evaluated using the detailed analysis criteria presented in Section 4.1. Alternatives are evaluated by medium and environmental setting, as discussed previously:

- Surface soil (Tables 4-1 through 4-5)
- Subsurface soil (Tables 4-6 through 4-8)
- Groundwater (Tables 4-9 through 4-12)
- HBHA Pond sediment (Tables 4-13 through 4-17)
- Near-shore sediment (Tables 4-18 through 4-21)
- Deep sediment (Tables 4-22 through 4-24), and
- Surface water (Tables 4-25 through 4-27).

Although the alternatives are media-specific, in many cases the media and alternatives are inter-related such that one alternative for a particular medium may impact the analysis of a remedial alternative for other downgradient media. For example, since contaminated groundwater discharges are responsible for sediment contamination in the HBHA Pond, the analysis of sediment alternatives would be contingent upon the actions taken to address contaminated groundwater discharges to the Pond. Where applicable, these dependent relationships are noted in the detailed analysis of alternatives.

The following sections of text provide descriptions of the major components of each alternative. The detailed analysis of alternatives is presented in table form only.

4.2.1 Individual Analysis of Soil Alternatives

Contaminated soil was identified in the former Mishawum Lake bed area. Potential risks to human health under potential future exposure scenarios were identified for surface soils (0 to 3 feet below ground surface) and subsurface soils (3 to 15 feet). The RAO for soil is as follows:

► **Prevent exposures associated with a HI > 1 and/or ILCR > 10^{-6} to 10^{-4} by meeting the associated PRGs for the following scenarios:**

- *Ingestion and dermal contact of arsenic by children at a future day care center for surface and subsurface soil*
- *Ingestion and dermal contact of arsenic by a future excavation worker for subsurface soil*

In order to meet these RAOs, a PRG of 50 mg/kg was established for both surface soil and subsurface soil. In order to meet the RAOs and PRGs for soil, the following remedial alternatives were established based on the alternative screening presented in Section 3.0:

<u>Surface Soil (SS)</u>:

- Alternative SS-1: No Action
- Alternative SS-2: Institutional Controls with Monitoring
- Alternative SS-3: Permeable Cover and Monitoring with Institutional Controls
- Alternative SS-4: Excavation and Off-Site Disposal
- Alternative SS-5: Excavation , Treatment, and On-Site Reuse

<u>Subsurface Soil (SUB)</u>:

- Alternative SUB-1: No Action
- Alternative SUB-2: Institutional Controls with Monitoring
- Alternative SUB-3: Permeable Cover and Monitoring with Institutional Controls

A general description of the major components of each alternative is provided in the following sections. The areas requiring remediation are presented in Figure 2-3A for surface soils and Figure 2-3B for subsurface soils.

For the purposes of this FS, surface soils and subsurface soil alternatives were evaluated independently. However, since the area requiring remediation for surface soils is contained within the limits for subsurface soil remediation, the selected remedial alternative should be coordinated to avoid duplication of effort and costs. For example, if a permeable cover is selected for both the surface soil and subsurface soil, the costs for the surface soil remedy would already be accounted for in the subsurface soil alternative.

4.2.1.1 Alternative SS-1: No Action

Under this alternative, no remedial technologies would be implemented at the Site to reduce arsenic concentrations in surface soils. No degradation of arsenic would be anticipated from naturally occurring processes, therefore no reduction in risks to human health would be achieved. A summary of ARARs associated with this alternative is presented on Tables 4-1A through 4-1C. The evaluation of this alternative against the NCP criteria is presented on Table 4-1D. Contaminants would remain at the Site above levels that allow for unlimited use and unrestricted exposure, therefore a formal review of site conditions and risks would need to be performed at least once every five years.

4.2.1.2 Alternative SS-2: Institutional Controls With Monitoring

Alternative SS-2 (Institutional Controls with Monitoring) does not involve treatment or removal, but provides protection of human health by controlling potential exposures to contaminated soil through the implementation of institutional controls. Institutional controls that would be implemented under this alternative would include prohibitions on the use of impacted properties for a day care facility and prohibitions on excavation without regulatory oversight and adequate worker health and safety precautions (engineering controls, PPE) to minimize or prevent direct contact with contaminated soil during removal activities and to control the potential onsite and offsite spread of contamination.

No degradation of arsenic is anticipated to occur from naturally occurring processes. Therefore, a groundwater monitoring component is included to ensure that contaminated soils that are left in-place do not impact groundwater and create unacceptable human health risks or hazards in the future. A network of permanent groundwater monitoring wells would be installed to enable groundwater monitoring. Groundwater samples would be collected semi-annually for the first five years and annually for years 5 through 10. After year 10, if contaminant trends show that there have been no impacts to groundwater such that no human health risks or hazards have been created, then groundwater sampling would be suspended or discontinued.

A summary of ARARs associated with this alternative is presented on Tables 4-2A through 4-2C. The evaluation of this alternative against the NCP criteria is presented on Table 4-2D. The primary components of this alternative would include:

- Conducting a pre-design investigation to delineate the limits of soil contamination so that properties requiring institutional controls may be identified;
- Mobilization and demobilization of required personnel and equipment to conduct property surveys;
- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents;
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Installation of permanent monitoring wells;
- Periodic sampling of the groundwater monitoring wells and reporting;
- Long-term inspections to ensure that that the deed restrictions are being enforced; and
- Performance of 5-year reviews to monitor the effectiveness of the remedy.

4.2.1.3 Alternative SS-3: Permeable Cover and Monitoring with Institutional Controls

Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) does not involve treatment or complete removal of contaminated soil, but provides protection of human health by preventing or controlling potential exposures to contaminated soil through the construction of a protective barrier or cap over the contaminated soils. Under this alternative, a permeable cover would be constructed to prevent future exposures to contaminated surface soil in the former Mishawum Lake bed area. Existing paved surfaces and building foundation and slabs would be evaluated for suitability as equivalent cover so that these surfaces would not have to be removed. Areas unsuitable as equivalent cover would require removal of surface soils (approximately 18 inches) and construction of an engineered permeable cover. In addition, institutional controls would be required to ensure that the cover, including equivalent structures such as asphalt paved areas and building foundations, is adequately protected through deed restrictions and maintenance.

No degradation of arsenic is anticipated from naturally occurring processes. Therefore, a groundwater monitoring component is included to ensure that contaminated soils that are left in-place do not impact groundwater and create unacceptable human health risks or hazards in the future. A network of permanent groundwater monitoring wells would be installed to enable groundwater monitoring. Groundwater samples would be collected semi-annually for the first 5 years and annually for years 5 through 10. After year 10, if contaminant trends show that there have been no impacts to groundwater such that no human health risks or hazards have been created, then groundwater sampling would be suspended or discontinued.

A summary of ARARs associated with this alternative is presented on Tables 4-3A through 4-3C. The evaluation of this alternative against the NCP criteria is presented on Table 4-3D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and construct property-specific covers;
- Components of institutional controls as identified for Alternative SS-2 (Institutional Controls with Monitoring);
- Mobilization and demobilization of required personnel and equipment to the Site for construction of the permeable cover:
    - Conducting a pre-design investigation to delineate the limits of contamination requiring remediation;
    - Limited excavation of approximately 6,600 cubic yards of contaminated surface soil to provide adequate depth and subgrade for the permeable cover materials;
    - Placement of a geotextile or other engineered barrier to prevent direct contact with the soil. (It is assumed that existing paved surfaces and building slabs will be adequate to offer protection as equivalent cover. Some minor pavement repairs are assumed;
    - Placement of backfill and surface treatment to match the intended use (planter beds, asphalt pavement, concrete, etc.); and
    - Transportation and disposals of contaminated soils at an approved licensed facility.

- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Installation of permanent monitoring wells;
- Periodic sampling of the groundwater monitoring wells and reporting;
- Long-term inspections to ensure that the deed restrictions are being enforced; and
- Performance of 5-year reviews to monitor the effectiveness of the permeable cover.

4.2.1.4 Alternative SS-4: Excavation and Off-Site Disposal

Under this alternative, all source area materials exceeding the arsenic PRG will be excavated and transported for offsite disposal at an approved, licensed facility. This alternative assumes that the soils underlying existing buildings would likely have been imported structural fill placed during construction of the building and will not require remediation. This alternative would provide permanent elimination of risks to human health resulting from future exposures to arsenic in surface soils. Note that if the pre-design investigation conducted to delineate the limits of contamination determine that the soils under a building do exceed the arsenic PRG, then institutional controls would be required until such time as the soils could be removed, such as during building demolition (see Alternative SS-2 for the components of institutional controls).

A summary of ARARs associated with this alternative is presented on Tables 4-4A through 4-4C. The evaluation of this alternative against the NCP criteria is presented on Table 4-4D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners for excavation of contaminated surface soil;
- Mobilization and demobilization of required personnel and equipment to the site for excavation of the contaminated soils:
    - Conducting a pre-design investigation to delineate the limits of contamination requiring remediation;
    - Excavation of approximately 63,600 cubic yards of contaminated surface soil to a depth of 3 feet;
    - Site restoration including placement of backfill and surface treatment to match the pre-construction conditions (planter beds, asphalt pavement, concrete, etc.; and

    - Transportation and disposal of contaminated soils at an approved licensed facility.
- Since no contaminants would be left on site above PRGs, five-year reviews would not be required for this alternative.

4.2.1.5 Alternative SS-5: Excavation, Treatment, and On-Site Reuse

This alternative is identical to Alternative SS-4 (Excavation and Off-Site Disposal) except that the excavated soil contaminated at levels above PRGs would be treated onsite to remove arsenic and then placed back into the excavations. No offsite disposal of wastes would be required except those wastes generated during the treatment process (i.e. contaminated rinsate).

This alternative would provide permanent elimination of risks to human health resulting from future exposures to arsenic in surface soils. Note that if the pre-design investigation conducted to delineate the limits of contamination determine that the soils under a building do exceed the arsenic PRG, then institutional controls would be required until such time as the soils could be removed, such as during building demolition (see Alternative SS-2 for the components of institutional controls).

A summary of ARARs associated with this alternative is presented on Tables 4-5A through 4-5C. The evaluation of this alternative against the NCP criteria is presented on Table 4-5D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners for excavation and onsite treatment of contaminated soils;
- Mobilization and demobilization of required personnel and equipment to the site for construction of the permeable cover:
    - Site preparation for soil treatment area;
    - Conducting a pre-design investigation to delineate the limits of contamination requiring remediation;
    - Excavation of approximately 63,600 cubic yards of contaminated surface soil to a depth of 3 feet;
    - Hauling wastes to a central treatment area;

  - Treating arsenic contaminated soils using a treatment train approach that includes soil pre-treatment, acid extraction, rinsing, and dewatering;
  - Site restoration including placement of treated soil into excavations and applying surface treatment to match the pre-construction conditions (planter beds, asphalt pavement, concrete, etc.); and
  - Transportation and disposals of contaminated rinsate solutions at an approved licensed facility
- Since no contaminants would be left on site above PRGs, five-year reviews would not be required for this alternative.

4.2.1.6 Alternative SUB-1: No Action

Under this alternative, no remedial technologies would be implemented at the Site to reduce arsenic concentrations in surface soils. No degradation of arsenic would be anticipated from naturally occurring processes, therefore no reduction in risks to human health would be achieved. A summary of ARARs associated with this alternative is presented on Tables 4-6A through 4-6C. The evaluation of this alternative against the NCP criteria is presented on Table 4-6D. Contaminants would remain at the Site above levels that allow for unlimited use and unrestricted exposure, therefore a formal review of site conditions and risks would need to be performed at least once every five years.

4.2.1.7 Alternative SUB-2: Institutional Controls with Monitoring

Alternative SUB-2 (Institutional Controls with Monitoring) addresses soils within the zone of 3 feet to 15 feet below the surface that exceed the PRG. Human health risks and hazards associated with these contaminated subsurface soils are only present if the soils are excavated, causing a construction worker exposure; or excavated and re-distributed to the ground surface causing a potential exposure to a day care child. Alternative SUB-2 (Institutional Controls with Monitoring) is an alternative that does not involve treatment or removal, but provides protection of human health by preventing or controlling potential exposures to contaminated soil through implementation of institutional controls. Institutional controls would take the form of deed restrictions and/or other appropriate institutional controls whereby excavations in this area would be prohibited unless adequate precautions (engineering controls, PPE, monitoring, etc.)

were taken to minimize or prevent direct contact with contaminated soil during or after removal activities.

No degradation of arsenic is anticipated from naturally occurring processes. Therefore, a groundwater monitoring component is included to ensure that contaminated soils that are left in-place do not impact groundwater and create unacceptable human health risks or hazards in the future. A network of permanent groundwater monitoring wells would be installed to enable groundwater monitoring. Groundwater samples would be collected semi-annually for the first five years and annually for years 5 through 10. After year 10, if contaminant trends show that there have been no impacts to groundwater such that no human health risks or hazards have been are created, then groundwater sampling could be suspended or discontinued.

A summary of ARARs associated with this alternative is presented on Tables 4-7A through 4-7C. The evaluation of this alternative against the NCP criteria is presented on Table 4-7D. The primary components of this alternative would include:

- Conducting a pre-design investigation to delineate the limits of contamination requiring Institutional Controls;
- Mobilization and demobilization of required personnel and equipment to conduct property surveys;
- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents;
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Installation of permanent monitoring wells;
- Periodic sampling of the groundwater monitoring wells and reporting;
- Long-term inspections to ensure that the deed restrictions are being enforced; and
- Performance of 5-year reviews to monitor the effectiveness of the remedy.

4.2.1.8 Alternative SUB-3: Permeable Cover and Monitoring with Institutional Controls

Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) is similar to Alternative SS-3 (Permeable Cover with Institutional Controls) except that it addresses a considerably larger area, representing the locations with subsurface arsenic PRG exceedances. This alternative does not involve treatment, but provides protection of human health by preventing or controlling potential exposures to contaminated soil through the construction of a protective barrier or cap over the contaminated soils.

Under this alternative, a permeable cover would be constructed to prevent future exposures to contaminated subsurface soil in the former Mishawum Lake bed area. As with Alternative SS-3 (Permeable Cover with Institutional Controls), existing paved surfaces and building foundation and slabs would be evaluated for suitability as equivalent cover so that these surfaces would not have to be removed.

In order to construct the cap, limited removal of surface soils (approximately 18 inches) must be conducted to install the cover and maintain the existing grades. Since the area of surface soils requiring remediation is contained within the assumed limits of the subsurface soil remediation area, these soils (approximately 6,600 cubic yards) are assumed to exceed the arsenic PRG and will require off-site disposal. All other surface soils within the limits of the subsurface soil remedy area are assumed to be below the arsenic PRG and will be excavated, temporarily stockpiled, and later reused as backfill. In addition, institutional controls would be required to ensure that the cover, including the equivalent cover such as asphalt paved areas and building foundations, is protected through deed restrictions and long-term maintenance.

No degradation of arsenic is anticipated from naturally occurring processes. Therefore, a groundwater monitoring component would be included to ensure that contaminated soils left in-place do not impact groundwater and create unacceptable human health risks or hazards in the future. A network of permanent groundwater monitoring wells would be installed to enable groundwater monitoring. Groundwater samples would be collected semi-annually for the first five years and annually for years 5 through 10. After year 10, if contaminant trends show that there have been no impacts to groundwater such that no human health risks or hazards have been are created, then groundwater sampling would be suspended or discontinued.

A summary of ARARs associated with this alternative is presented on Tables 4-8A through 4-8C. The evaluation of this alternative against the NCP criteria is presented on Table 4-8D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and construct property-specific covers;
- Components of institutional controls as identified for Alternative SUB-2 (Institutional Controls with Monitoring);
- Conducting a pre-design investigation to delineate the limits of contamination requiring a permeable cover;
- Mobilization and demobilization of required personnel and equipment to the site for construction of the permeable cover:
    - Limited excavation of surface soils to provide adequate depth and subgrade for the permeable cover materials;
    - Placement of a geotextile or other engineered barrier to prevent direct contact with the soil over an estimated area of 275,000 square feet. (It is assumed that existing paved surfaces and building slabs will be adequate to offer protection as equivalent cover; some minor pavement repairs are estimated.); and
    - Placement of backfill and surface treatment to match the intended use (planter beds, asphalt pavement, concrete, etc.).
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Installation of permanent monitoring wells;
- Periodic sampling of the groundwater monitoring wells and reporting;
- Long-term inspections by to ensure that the deed restrictions are being enforced, and
- Performance of 5-year reviews to monitor the effectiveness of the permeable cover.

4.2.2 Individual Analysis of Groundwater Alternatives

Contaminated groundwater, principally originating at the Industri-plex Site, was identified within Reach 0. The fate and transport evaluation for groundwater indicates that contaminated groundwater flows to and discharges primarily into the HBHA Pond. Potential risks and hazards to humans under future exposure scenarios were identified for groundwater in the areas depicted on Figure 2-4. In addition, sediment and surface water contamination resulting from groundwater discharges to the HBHA Pond have been shown to present risks to benthic aquatic life, in particular benthic invertebrates.

Groundwater discharges to the Pond, and sediment and surface water contamination that results from these discharges, may also result in downstream migration of contaminants and future impacts to downstream depositional areas. For this reason, the evaluation of sediment and surface water alternatives is, in some cases, dependent upon the actions taken to address groundwater contamination. Where applicable, the detailed analysis of groundwater alternatives addresses the interactions between media and the implications of groundwater alternatives on sediment and surface water quality. The RAOs developed for groundwater are as follows:

► **Prevent exposures associated with a HI > 1 and/or ILCR > 10^{-6} to 10^{-4} by meeting the associated PRGs for the following scenarios:**

- *Ingestion, dermal contact, and/or vapor inhalation of arsenic, benzene, trichloroethene, 1,2-dichloroethane, and naphthalene by an industrial worker using groundwater as process water*
- *Ingestion and dermal contact of arsenic by an excavation worker*
- *Vapor inhalation of benzene, trichloroethene, and 1,2-dichloroethane by a car wash worker using groundwater in the car wash*

► **Protect benthic invertebrates and aquatic life from exposure to levels of benzene and arsenic indicative of impairment due to groundwater discharges or provide alternate habitat (HBHA Pond only).**

In order to meet these RAOs, the PRGs for groundwater were established as follows:

Contaminant	PRG	HQ	ILCR
Arsenic	150 µg/L	0.3	4.E-05
Benzene	4 µg/L	0.1	1.E-05
1,2-Dichloroethane	2 µg/L	0.3	1.E-05
Trichloroethene	1 µg/L	0.02	3.E-05
Naphthalene	5 µg/L	1	----
	Cumulative Risk/Hazard	1	9.E-05

The RAOs and PRGs are also presented in Table 2-4 and 2-5, respectively. In order to meet the RAOs and PRGs for groundwater, the following remedial alternatives were established based on the alternative screening presented in Section 3.0:

- Alternative GW-1: No Action

- Alternative GW-2: Pond Intercept with Monitoring and Institutional Controls
- Alternative GW-3: Plume Intercept by Groundwater Extraction, Treatment and Discharge and Monitoring with Institutional Controls
- Alternative GW-4: Plume Intercept by In-Situ Groundwater Treatment and Monitoring with Institutional Controls

The individual analyses and a general description of the major components of each alternative are provided in the following sections.

4.2.2.1 Alternative GW-1: No Action

Under this alternative, no remedial technologies would be implemented at the Site to reduce arsenic, benzene, TCE, naphthalene, or 1,2-DCA concentrations within groundwater. The alternative would not limit potential human or ecological exposures to contaminated groundwater and would not prevent future discharges of contaminated groundwater to surface water within the HBHA Pond. There would be no measures taken to restrict the future use of groundwater that is contaminated with these contaminants. Groundwater that is contaminated with arsenic would continue to migrate southward with the flow of groundwater and discharge into the HBHA Pond, and continue to provide a source of contamination to surface water and sediments in the HBHA Pond, the downstream HBHA wetlands, the Aberjona River and adjacent wetlands. No degradation of arsenic is anticipated from naturally occurring processes.

A summary of ARARs associated with this alternative is presented on Tables 4-9A through 4-9C. The evaluation of this alternative against the NCP criteria is presented on Table 4-9D.

4.2.2.2 Alternative GW-2: Pond Intercept with Monitoring and Institutional Controls

Alternative GW-2 (Pond Intercept with Monitoring and Institutional Controls) is an alternative that involves little or no active treatment, but provides protection of human health by preventing or controlling potential exposures to contaminated groundwater through institutional controls. The alternative also controls the downstream migration of the contaminated groundwater to areas in the HBHA wetlands and the Aberjona River by intercepting it at the HBHA Pond where natural processes in the HBHA Pond are degrading or sequestering the contaminants of concern such that no unacceptable human health or ecological risks are present downstream of the HBHA Pond. Alternative GW-2 (Pond Intercept with Monitoring and Institutional Controls) would rely upon other sediment and surface water alternatives to address these contaminants within the HBHA Pond itself.

Although degradation of organics in site-wide groundwater is anticipated over time through natural processes, the degradation of arsenic is not expected. This alternative would not limit potential ecological exposures to contaminated groundwater in the HBHA Pond and would not prevent future discharges of contaminated groundwater to surface water within the HBHA Pond. Although contaminated groundwater would be intercepted at the HBHA Pond and contaminants would be sequestered at the Pond bottom, contaminated groundwater would continue to discharge into the HBHA Pond and continue to provide a source of contamination to surface water and sediments in the HBHA Pond.

A summary of ARARs associated with this alternative is presented on Tables 4-10A through 4-10C. The evaluation of this alternative against the NCP criteria is presented on Table 4-10D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents;
- Mobilization and demobilization of required personnel and equipment to the site to conduct property surveys and conduct periodic sampling;
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Long-term inspections to ensure that the deed restrictions are being enforced;
- Long-term monitoring of groundwater, surface water, and sediments to evaluate contaminant status and migration, and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.2.3 Alternative GW-3: Plume Intercept by Groundwater Extraction, Treatment and Discharge and Monitoring with Institutional Controls

Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) is an active groundwater extraction and treatment alternative. This alternative would consist of installing a groundwater extraction system that would capture groundwater from the overburden aquifer within the contaminant plumes that were delineated based on the results of the human health risk assessment prior to discharge into the HBHA Pond (see Figure 2-4).

The implementation of Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) would achieve several objectives through the extraction and treatment of contaminated groundwater originating from the Industri-plex Site. These include plume containment; prevention of the continued discharge of groundwater contaminants into the HBHA Pond; prevention of the continued migration of groundwater contaminants through surface water and sediments to the HBHA Pond, HBHA wetlands, Aberjona River, and adjacent wetlands; and reduction of ecological risks observed in the HBHA Pond deep surface water and sediment due to contaminated groundwater discharges.

In addition, GW-3 would incorporate in-situ enhanced bioremediation through oxygen injection to treat the source areas for organic contaminants (benzene) at the West Hide Pile, an area located outside of the capture zone of the proposed groundwater extraction system.

Due to the presence of contaminants in soil throughout the site area, there will be continued leaching of contamination from the soil source areas that impacts groundwater such that the groundwater extraction system would not be expected to achieve RAOs within a reasonable time period. Therefore, institutional controls to prevent groundwater withdrawals would also be required under Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) to address potential human health risks and hazards associated with direct contact, inhalation, and ingestion.

A summary of ARARs associated with this alternative is presented on Tables 4-11A through 4-11C. The evaluation of this alternative against the NCP criteria is presented on Table 4-11D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and construct the extraction and treatment system as well as the discharge component;
- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents;

- Mobilization and demobilization of required personnel and equipment to the site to conduct property surveys and conduct periodic sampling;
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Mobilization and demobilization of required personnel and equipment to the site for construction of the extraction and treatment system:
    - Property and construction surveys;
    - Installation of approximately six groundwater extraction wells (total extraction rate approximately equal to 200 gpm);
    - Clearing, grubbing and site prep for treatment plant;
    - Construction of treatment plant foundations and building structure;
    - Installation of underground piping from the extraction well to the treatment plant;
    - Installation, connection, startup, and testing of all extraction and treatment equipment;
    - Installation of oxygen injection wells and initial injection/application of the specified oxygen releasing compound, and
    - Site restoration.
- Long-term operation and maintenance of the extraction and treatment system;
- Long-term monitoring of groundwater, surface water, and sediments to evaluate effectiveness of groundwater capture and treatment;
- Long-term inspections to ensure that the institutional controls are being enforced, and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.2.4 Alternative GW-4: Plume Intercept by In-Situ Groundwater Treatment and Monitoring with Institutional Controls

Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment and Monitoring with Institutional Controls) is an in-situ groundwater treatment alternative that incorporates two technologies to address both organic and inorganic contaminants in groundwater; in-situ enhanced bioremediation through oxygen injection would be used to treat the source areas for organic contaminants (benzene, TCE, 1,2-DCA, and naphthalene) located between the East-Central Hide Pile and the South Hide Pile in the vicinity of Atlantic Avenue, and at the West Hide Pile for benzene; and a permeable reactive barrier (PRB) located between the southern perimeter of the NSTAR (formerly Boston Edison) right-of-way and the HBHA Pond would be used for the treatment of arsenic in groundwater prior to discharge to the Pond. Figure 4-1 presents a conceptual representation of the location of the PRB and the location of the bio-enhancement treatment area at the West Hide Pile.

As with Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring), these two in-situ treatment processes together would achieve several objectives including prevention of continued migration of groundwater contaminants into the HBHA Pond, HBHA, and Aberjona River and reduction of ecological risks observed in the HBHA Pond deep surface water and sediment due to continued contaminated groundwater discharges. However, due to the nature of the PRB treatment (the PRB would intercept groundwater as it flows to the Pond rather than actively treat it throughout the groundwater plume area), concentrations of arsenic in excess of the PRG would remain throughout the human health risk areas. Therefore, institutional controls that prohibit groundwater withdrawals would be required to address potential human health risks and hazards associated with direct contact, inhalation, and ingestion exposures.

A summary of ARARs associated with this alternative is presented on Tables 4-12A through 4-12C. The evaluation of this alternative against the NCP criteria is presented on Table 4-12D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents;
- Mobilization and demobilization of required personnel and equipment to the site to conduct property surveys, perform necessary pre-design investigations, and conduct periodic sampling;
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Coordination with local, state, and federal agencies and property owners to design and construct the in-situ oxidation system and the PRB;
- Mobilization and demobilization of required personnel and equipment to the site for construction of the treatment system:
    - Property and construction surveys;
    - Installation of the bio-enhancement/oxygen injection wells and initial injection/application of the specified oxygen releasing compound;

  - Clearing, grubbing and site prep for the PRB;
  - Construction of the PRB, and
  - Site restoration.
- Long-term maintenance of the PRB including periodic change out of the reactive wall material;
- Long-term operation and maintenance of the oxidant injection system including periodic injections of oxidation materials;
- Long-term monitoring of groundwater, surface water, and sediments to evaluate effectiveness of in-situ and PRB systems;
- Long-term inspections to ensure that the deed restrictions are being enforced, and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.3 Individual Analysis of Sediment Alternatives

Sediment contaminated primarily with arsenic was determined to present potential current and/or future risks and hazards to humans at locations near the edge of the wetland (near shore) within the Wells G&H wetland and the Cranberry Bog Conservation Area, and potential future risks and hazards to humans at deeper sediment locations within isolated areas in the HBHA wetland and the Aberjona River channel identified through sediment core samples. In addition, sediment in the HBHA Pond was determined to present unacceptable ecological risks to benthic invertebrates.

The RAOs for sediment are as follows:

HUMAN HEALTH
► **Prevent exposures associated with a HI > 1 and/or ILCR > 10^{-6} to 10^{-4} by meeting the associated PRGs for the following scenarios:**
● *Ingestion and dermal contact of accessible arsenic and benzo(a)pyrene for current and future recreational land use*
● *Ingestion and dermal contact of accessible arsenic for current and future recreational land use*
● *Ingestion and dermal contact of arsenic for future dredging workers*

ECOLOGICAL (HBHA Pond only)
► **Protect benthic invertebrates from toxicological impacts indicative of impairment or provide alternate habitat.**
► **Minimize to the extent practicable, the migration of soluble and particulate arsenic during storm events to downstream depositional areas.**

In order to meet these RAOs, the following PRGs were established for sediments:

Near Shore Sediments in the Cranberry Bog Conservation Area	**PRG**	**HQ**	**ILCR**
Arsenic	230 mg/kg	1	6.E-05
Near Shore Sediments in the Wells G&H Wetland			
Arsenic	300 mg/kg	1	6.E-05
Benzo(a)pyrene	4.9 mg/kg	---	1.E-05
	Cumulative Risk/Hazard	1	7.E-05
Deep Sediments in the HBHA and Wells G&H Wetlands			
Arsenic	300 mg/kg	0.8	1.E-05
HBHA Pond Sediments (ecological risk only)			
Arsenic	273 mg/kg	NA	NA

The RAOs and PRGs that were developed to address risks associated with sediment contamination are also presented in Table 2-4 and 2-5, respectively. In order to meet the RAOs and PRGs for sediments, the following remedial alternatives were established based on the alternative screening presented in Section 3.0:

<u>HBHA Sediments (HBHA)</u>

- Alternative HBHA-1: No Action
- Alternative HBHA-2: Monitoring
- Alternative HBHA-3: Subaqueous Cap
- Alternative HBHA-4: Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat
- Alternative HBHA-5: Removal and Off-Site Disposal

Near Shore Sediments (NS)

- Alternative NS-1: No Action
- Alternative NS-2: Institutional Controls
- Alternative NS-3: Monitoring with Institutional Controls
- Alternative NS-4: Removal and Off-Site Disposal

Deep Sediments (DS)

- Alternative DS-1: No Action
- Alternative DS-2: Monitoring with Institutional Controls
- Alternative DS-3: Removal and Off-Site Disposal

The individual analysis of sediment alternatives and a general description of the major components of each alternative are provided in the following sections. It should be noted that, in some cases, the ability of alternatives to address contaminated sediments in the HBHA Pond are dependent upon the alternative that is selected to address groundwater contamination, since contaminated groundwater discharges are the source of sediment contamination. Where applicable, these contingencies are noted in the detailed analysis of sediment alternatives.

4.2.3.1 Alternative HBHA-1: No Action

Under this alternative, no remedial technologies would be implemented to reduce arsenic concentrations within the sediments of the HBHA Pond. No degradation of arsenic is anticipated from naturally occurring processes within the HBHA Pond, therefore no reduction in ecological risk would be achieved. Five-year reviews would be required if this alternative were to be implemented.

A summary of ARARs associated with this alternative is presented on Tables 4-13A through 4-13C. The evaluation of this alternative against the NCP criteria is presented on Table 4-13D.

4.2.3.2 Alternative HBHA-2: Monitoring

Alternative HBHA-2 (Monitoring) incorporates long-term monitoring to evaluate possible changes to the nature and extent and migration patterns of contaminated sediments and risks to benthic invertebrates over time. Alternative HBHA-2 (Monitoring) would not address ecological risks or control the migration of contaminated sediments to downstream areas. However, if contaminated groundwater discharges are eliminated (through interception of the groundwater contaminant plume before it reaches the Pond, as provided by Alternative GW-3 or GW-4), natural processes such as biodegradation of organic contaminants and sedimentation and burial of inorganic contaminants may eventually reduce the exposure risks, toxicity, and mobility of the benzene and arsenic that is currently located in sediments at the Pond bottom.

A summary of ARARs associated with this alternative is presented on Tables 4-14A through 4-14C. The evaluation of this alternative against the NCP criteria is presented on Table 4-14D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop long-term monitoring requirements;
- Mobilization and demobilization of required personnel and equipment to the site to conduct periodic sampling;
- Long-term monitoring of groundwater, surface water, and sediments to evaluate contaminant status, migration, and potential impact to biota, and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.3.3 Alternative HBHA-3: Subaqueous Cap

Alternative HBHA-3 (Subaqueous Cap) does not involve treatment or removal, but provides protection of the environment from contaminated sediments by preventing or controlling direct contact exposures to benthic invertebrates and by preventing migration of contaminated sediments to downstream areas. Alternative HBHA-3 (Subaqueous Cap) includes the placement of a subaqueous cap consisting of a geotextile layer covered with clean permeable soil materials over contaminated sediments at the base of the HBHA Pond, creating a new benthic habitat and an effective barrier from existing sediment contaminants. Alternative HBHA-3 (Subaqueous Cap) would address ecological risks, but would not address the source of contamination (i.e. groundwater discharges) which could, over time, result in recontamination of the clean cap materials if a plume intercept alternative is not utilized to address groundwater.

A summary of ARARs associated with this alternative is presented on Tables 4-15A through 4-15C. The evaluation of this alternative against the NCP criteria is presented on Table 4-15D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and construct the subaqueous cap;
- Mobilization and demobilization of required personnel and equipment to the site for construction of the subaqueous cap:
    - Limited clearing and grubbing for equipment and materials laydown areas;
    - Installation of silt curtains, sedimentation booms and other equipment to prevent downstream migration of sediments during cap placement;
    - Dewatering of the pond, treatment and discharge of dewatering liquids;
    - Placement of cap materials.
- Long-term inspections and maintenance of the cap to ensure erosional forces have not deteriorated the cap's thickness thus reducing its effectiveness;
- Long-term monitoring of groundwater, surface water, sediments and biota to evaluate cap effectiveness and re-colonization of biota on the cap surface, and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.3.4 Alternative HBHA-4: Storm Water Bypass and Sediment Retention With Partial Dredging and Providing an Alternate Habitat

Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) involves partial removal of contaminated sediments and reduces the mobility of soluble and particulate arsenic that is released from the HBHA Pond during storm events to downstream depositional areas. In the portion of the HBHA Pond where contaminated sediments are dredged, this alternative would protect the environment by preventing exposure of benthic invertebrates to contaminated sediments. This alternative would not protect the environment in the northernmost portion of the HBHA Pond, which would be used as a sediment retention area.

Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) would involve the construction of two low-head cofferdams designed to divide the HBHA Pond into three main areas. The northernmost area of the HBHA

Pond, into which contaminated groundwater would be permitted to discharge, would be isolated from the southern portions of the HBHA Pond by the northern cofferdam. Contaminated sediments would not be dredged from this area, and it would be utilized as a sediment retention area that would prevent the migration of contaminated sediment to the south. A second cofferdam would be constructed to the south to create a secondary treatment zone that would be utilized to “polish” surface water that leaves the sediment retention area through the use of aeration and sedimentation. Contaminated sediments would be dredged from this area as necessary, which would also serve as a back-up retention area in the event that high flows or other unforeseen circumstances cause excessive arsenic loading to flow over the first cofferdam.

A second component of Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) would be the diversion of storm flow from Halls Brook to avoid high flow volumes into the sediment retention area that would break down the chemocline. Stormwater flow that would otherwise enter the northern portion of the HBHA Pond would instead be diverted to the south of the cofferdams so that base flow conditions are maintained in the sediment retention area. By retaining base flow conditions in the sediment retention area, the downstream migration of contaminated sediment that currently occurs during storm events would be prevented.

Contaminated sediments containing arsenic at concentrations exceeding the PRG would be dredged from the portions of the HBHA Pond located to the south of the northern cofferdam (this includes the secondary treatment area as well as the southern portion of the HBHA Pond up to its outlet to the Halls Brook Holding Area). Hydraulic dredging methods would be utilized to permanently remove contaminated sediments from these areas of the HBHA Pond. Sediments would be dewatered and transported to an approved licensed disposal facility. Periodic dredging in the sediment retention area would also be a component of this remedy to prevent excessive accumulation of sediments and maintain the integrity of the chemocline and the function of the sediment retention area.

As part of Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat), an impermeable liner would be placed along a section of the New Boston Street Drainway to prevent arsenic-contaminated groundwater from discharging into the New Boston Street Drainway. The contaminated groundwater discharges could contaminate sediments in the channel and ultimately enable the transport of contaminated sediment into the southern portion of the HBHA Pond (the portion of the Pond from which contaminated sediments would be removed) during storm events.

Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) would also involve stabilization of the northern banks of the HBHA Pond, located along the southern boundary of the Boston Edison right-of-way (A6 area) and adjacent to the railroad right of-way west f the HBHA Pond. This action would prevent soils contaminated with arsenic exceeding the HBHA Pond sediment PRG of 273 mg/kg from eroding into the northern portion of the Pond and contributing to the contaminated sediment load in the system.

In order to compensate for the habitat loss that would occur from the use of the northern portion of the HBHA Pond as a sediment retention area, Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) would involve wetland compensation to provide an alternate habitat for the impacted aquatic receptors.

Figure 4-3 presents a conceptual representation of HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) including the location of the storm water bypass structure, the cofferdams, and the soil/sediment erosion areas of concern. A summary of ARARs associated with this alternative is presented on Tables 4-16A through 4-16C. The evaluation of this alternative against the NCP criteria is presented on Table 4-16D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and construct the alternative;
- Conducting studies to locate property suitable for the construction of a compensatory wetland;
- Placing impermeable liner over approximately 1,000 linear feet of open channel along the southern section of the New Boston Street Drainway.
    - Limited clearing and grubbing for equipment and materials laydown areas;
    - Installation of sedimentation controls and installation of stream pump-around equipment;

  - Constructing a temporary support area for water treatment and dredge spoil stockpiling areas;
  - Excavation of stream bed sediments;
  - Installation of impermeable liner; and
  - Backfill of stream bed with stone and transition liner to existing geotextile cap.
- Mobilization and demobilization of required personnel and equipment to the site for construction of the permeable cover over the A6-area soils:
  - Conducting a pre-design investigation to delineate the limits of contamination requiring remediation;
  - Clearing and grubbing and limited subgrade preparation
  - Placement of a geotextile or other engineered barrier to prevent direct contact with the soil; and
  - Placement of backfill and revegetation.
- Filing of deed restrictions and providing a long-term maintenance program and/or other appropriate institutional controls;
- Mobilization and demobilization of required personnel and equipment to the site to construct the sediment retention area, construct the storm water bypass system, dredge contaminated sediments, and compensatory mitigation for wetland and stream losses:
  - Limited clearing and grubbing for equipment and materials laydown areas;
  - Installation of silt curtains sedimentation booms and other equipment to prevent downstream migration of sediments during construction in the pond and during dredging;
  - Construction of the dual low-head cofferdams;
  - Installation of aeration system;
  - Construction of the storm water by-pass structure at the mouth of Halls Brook;
  - Constructing temporary support area for water treatment and dredge spoil stockpiling areas;
  - Dredging of approximately 6,200 cubic yards of contaminated sediments in the southern portion of the HBHA Pond;
  - Continuous treatment of water generated during sediment dredging;
  - Dewatering and off-site disposal of dredged sediments;
  - Replacement of wetland substrate that was removed;
  - Restoration of all areas impacted during construction, and
  - Construction of the compensatory wetland.

- Long-term inspections and maintenance of the low-head cofferdams and storm water by-pass structure;
- Long-term maintenance and inspections and periodic removal of accumulated sediments from the sediment retention portion of the HBHA Pond;
- Long-term monitoring of groundwater, surface water, sediments and biota to evaluate alternative effectiveness and re-colonization of biota in the dredged area, and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.3.5 Alternative HBHA-5: Removal and Off-Site Disposal

Under this alternative, all contaminated sediments in the HBHA Pond that exceed the arsenic PRG (273 mg/kg) would be removed using hydraulic dredging methods, dewatered, and transported offsite for disposal at an approved licensed facility. This alternative would provide permanent elimination of risks to ecological receptors resulting from exposures to contaminated sediments in the HBHA Pond, but would not address the source of contamination (i.e. groundwater discharges from the Industri-plex Site) which could result in recontamination of the uncontaminated underlying or replacement substrate following dredging. In order for this alternative to be effective in the long term, a plume intercept alternative would need to be implemented to address contaminated groundwater discharges to the HBHA Pond so that the dredged portions of the Pond are not recontaminated.

In addition, Alternative HBHA-5 (Removal and Off-Site Disposal) would prevent arsenic-contaminated groundwater from discharging into the New Boston Street Drainway, which eventually discharges to Halls Brook, and would prevent arsenic-contaminated soils located along the southern boundary of the Boston Edison right-of-way (A6 area) from eroding into the northern portion of the HBHA Pond and contributing to the contaminated sediment load in the system.

A summary of ARARs associated with this alternative is presented on Tables 4-17A through 4-17C. The evaluation of this alternative against the NCP criteria is presented on Table 4-17D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and implement the alternative;

- Placing an impermeable liner over approximately 1,000 linear feet of open channel along the southern section of the New Boston Street Drainway.
    - Limited clearing and grubbing for equipment and materials laydown areas;
    - Installation of sedimentation controls and installation of stream pump-around equipment;
    - Constructing a temporary support area for water treatment and dredge spoil stockpiling areas;
    - Excavation of stream bed sediments;
    - Installation of impermeable liner; and
    - Backfill of stream bed with stone and transition liner to existing geotextile cap.
- Mobilization and demobilization of required personnel and equipment to the site for construction of the permeable cover over the A6-area soils:
    - Conducting a pre-design investigation to delineate the limits of contamination requiring remediation;
    - Clearing and grubbing and limited subgrade preparation;
    - Placement of a geotextile or other engineered barrier to prevent direct contact with the soil; and
    - Placement of backfill and revegetation.
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Mobilization and demobilization of required personnel and equipment to the site to dredge contaminated sediments:
    - Limited clearing and grubbing for equipment and materials laydown areas;
    - Installation of silt curtains sedimentation booms and other equipment to prevent downstream migration of sediments during dredging;
    - Constructing a temporary support area for water treatment and dredge spoil stockpiling areas;
    - Dredging of approximately 9,400 cubic yards of in-place contaminated sediments;
    - Continuous treatment of water generated during sediment dredging;
    - Dewatering and off-site disposal of dredged sediments;
    - Replacement of wetland substrate that was removed, and
    - Restoration of all areas impacted during construction.

- Long-term monitoring of groundwater, surface water, sediments and biota to evaluate alternative effectiveness and re-colonization of biota in the dredged area; and
- Performance of 5-year reviews to evaluate site conditions and risks and monitor the effectiveness of the impermeable and permeable covers.

4.2.3.6 Alternative NS-1: No Action

Under this alternative, no remedial technologies would be implemented to reduce arsenic concentrations in sediments within the near shore areas. These areas are located in the Well G&H wetland and the Cranberry Bog Conservation Area (see Figure 2-5b and 2-5c, respectively). This alternative would not reduce the risks to human health and would require the five-year reviews to periodically address site conditions and risks.

A summary of ARARs associated with this alternative is presented on Tables 4-18A through 4-18C. The evaluation of this alternative against the NCP criteria is presented on Table 4-18D.

4.2.3.7 Alternative NS-2: Institutional Controls

Alternative NS-2 (Institutional Controls) is an alternative that does not involve treatment or removal, but provides protection of human health by preventing or controlling potential exposures to contaminated sediment through installation of fencing to restrict access to contaminated sediment and through the imposition of institutional controls on impacted properties to prevent activities that might result in unacceptable exposures to contaminated near-shore sediments. Institutional controls would take the form of deed restrictions whereby land use would be restricted and excavations in this area would be prohibited unless adequate precautions (engineering controls, PPE) were taken to minimize or prevent direct contact with contaminated sediment during removal activities.

Alternative NS-2 (Institutional Controls) would achieve no risk reduction beyond that which would be provided by restricting access to contaminated near-shore sediments. A summary of ARARs associated with this alternative is presented on Tables 4-19A through 4-19C. The evaluation of this alternative against the NCP criteria is presented on Table 4-19D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents;
- Mobilization and demobilization of required personnel and equipment to the site to conduct property surveys, fencing design, and fencing installation;
- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Long-term inspections by local, state, and federal agencies to ensure that the fencing is being maintained properly and that the deed restrictions are being enforced; and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.3.8 Alternative NS-3: Monitoring with Institutional Controls

Alternative NS-3 (Monitoring with Institutional Controls) incorporates long-term monitoring to evaluate possible changes to the nature and extent and migration patterns of contaminated sediments in the near-shore areas combined with institutional controls as a remedy for near-shore contaminated sediment. Natural processes that may reduce the potential exposures and risks may include burial of the contaminated sediments by accumulation of uncontaminated sediments thus limiting the accessibility and risks due to direct contact exposures. Under this alternative, institutional controls would also be implemented to prevent future exposures to contaminated sediment in the vicinity of sampling stations where potential human health risks and hazards were identified. Finally, installation of a permanent barrier (i.e. chain link fence) would prevent access to contaminated sediments and human health risks associated with recreational exposures through direct contact.

A summary of ARARs associated with this alternative is presented on Tables 4-20A through 4-20C. The evaluation of this alternative against the NCP criteria is presented on Table 4-20D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents and long-term monitoring requirements;
- Mobilization and demobilization of required personnel and equipment to the site to conduct property surveys, fencing design, and fencing installation;

- Filing of deed restrictions and/or other appropriate institutional controls and providing a long-term maintenance program;
- Long-term inspections by local, state, and federal agencies to ensure that the fencing is being maintained properly and that the deed restrictions are being enforced;
- Long-term monitoring of surface water, and sediments to evaluate contaminant status and migration; and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.3.9 Alternative NS-4: Removal and Off-Site Disposal

Under this alternative, all near-shore contaminated sediments exceeding the arsenic PRG will be removed using mechanical excavation methods, dewatered, and transported offsite for disposal at an approved licensed facility. This alternative would provide permanent elimination of risks to humans resulting from exposures to contaminated near-shore sediments.

A summary of ARARs associated with this alternative is presented on Tables 4-21A through 4-21C. The evaluation of this alternative against the NCP criteria is presented on Table 4-21D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and implement the alternative;
- Mobilization and demobilization of required personnel and equipment to the site to excavate contaminated sediments:
  - Limited clearing and grubbing for haul roads and equipment and materials laydown areas;
  - Installation of silt curtains sedimentation booms and other equipment to prevent downstream migration of sediments during excavation;
  - Constructing a temporary support area for water treatment and excavation spoil dewatering and stockpiling areas;
  - Installing cofferdams or other means to hydraulically isolate excavation area from the open water portions of the wetland;
  - Dewatering excavations, as necessary;

  - Excavating approximately 2,340 cubic yards of contaminated sediments (2,114 cubic yards from the Wells G&H wetland areas and 226 cubic yards from the Cranberry Bog Conservation Area);
  - Treatment and wetland discharge of water generated during excavation and sediment dewatering;
  - Dewatering and off-site disposal of excavated sediments;
  - Constructing a transition zone permeable barrier separating contaminated sediments from clean/restored sediments and minimizing potential for recontamination during storm events;
  - Collecting and analyzing confirmatory sediment samples;
  - Replacement of wetland substrate and vegetation that was removed; and
  - Restoration of all areas impacted during construction;
- Short-term monitoring of biota to evaluate re-colonization of biota in the dredged area and revegetation; and
- Performance of 5-year reviews to evaluate site conditions, potential re-contamination, and associated risks.

4.2.3.10 Alternative DS-1: No Action

Under this alternative, no remedial technologies would be implemented to reduce arsenic concentrations in sediments located in deeper sediment cores collected in the river channel (see Figure 2-5d) . This alternative would not reduce the risks to human health and would require the performance of five-year reviews.

A summary of ARARs associated with this alternative is presented on Tables 4-22A through 4-22C. The evaluation of this alternative against the NCP criteria is presented on Table 4-22D.

4.2.3.11 Alternative DS-2: Monitoring with Institutional Controls

Alternative DS-2 (Monitoring with Institutional Controls) would address risks from future exposures to deep sediments by dredging workers through the use of institutional controls. Generally, these sediments are not accessible to humans except for in a dredging scenario, therefore prohibitions or restrictions on dredging would be an effective deterrent to potential future exposures to sediment in the deep sediment human health risk areas (Figure 2-5D).

Institutional controls would take the form of deed restrictions whereby dredging in these areas would be prohibited unless regulatory oversight and adequate precautions (e.g. engineering controls, PPE, etc.) were taken to minimize or prevent direct contact with contaminated sediment during dredging activities.

A summary of ARARs associated with this alternative is presented on Tables 4-23A through 4-23C. The evaluation of this alternative against the NCP criteria is presented on Table 4-23D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop property-specific deed restriction documents;
- Mobilization and demobilization of required personnel and equipment to the site to conduct property surveys;
- Filing of deed restrictions and/or other appropriate institutional controls;
- Long-term inspections by local, state, and federal agencies to ensure that the deed restrictions are being enforced; and
- Performance of 5-year reviews to evaluate site conditions, potential re-contamination, and associated risks.

4.2.3.12 Alternative DS-3: Removal and Off-Site Disposal

Under this alternative, all deep sediments associated with sediment core sample locations exceeding the arsenic PRG will be removed using mechanical excavation methods, dewatered, and transported offsite for disposal at an approved licensed facility. This alternative would provide permanent elimination of risks and hazards to humans resulting from exposures to contaminated deep sediment.

A summary of ARARs associated with this alternative is presented on Tables 4-24A through 4-24C. The evaluation of this alternative against the NCP criteria is presented on Table 4-24D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to design and implement the alternative;

- Mobilization and demobilization of required personnel and equipment to the site to dredge contaminated sediments:
  - Limited clearing and grubbing for equipment and materials laydown areas;
  - Installation of silt curtains sedimentation booms and other equipment to prevent downstream migration of sediments during dredging;
  - Constructing a temporary support area for water treatment and dredge spoil stockpiling areas;
  - Dredging of approximately 160,000 cubic yards of in-place contaminated sediments;
  - Continuous treatment of water generated during sediment dredging;
  - Dewatering and off-site disposal of dredged sediments;
  - Replacement of wetland substrate that was removed, and
  - Restoration of all areas impacted during construction.
- Long-term monitoring of groundwater, surface water, sediments and biota to evaluate alternative effectiveness and re-colonization of biota in the dredged area, and;
- Performance of 5-year reviews to evaluate site conditions, potential re-contamination, and associated risks.

4.2.4 Individual Analysis of Surface Water Alternatives

Contaminated surface water in the deeper portion of the HBHA Pond was determined to present unacceptable risks to aquatic organisms. Surface water in the HBHA Pond is also the principal transport process causing the migration of soluble arsenic and arsenic contaminated sediments to downstream areas. To address these risks, the following RAOs was developed for surface water in the HBHA Pond:

► Protect aquatic life from arsenic and benzene above levels indicative of impairment or provide alternate habitat. Meet ARARs for the protection of aquatic life.

In order to meet the surface water RAO, the following PRGs were established:

Contaminant	PRG	HQ	ILCR
Arsenic	150 µg/L	Not Applicable	Not Applicable
Benzene	46 µg/L	Not Applicable	Not Applicable

The RAOs and PRGs for surface water are also presented in Table 2-4 and 2-5, respectively. In order to meet the RAOs and PRGs for surface water, the following remedial alternatives were established based on the alternative screening presented in Section 3.0:

- Alternative SW-1: No Action
- Alternative SW-2: Monitoring
- Alternative SW-3: Monitoring and Providing an Alternate Habitat

The individual analysis and a general description of the major components of each alternative are provided in the following sections.

4.2.4.1 Alternative SW-1: No Action

Under this alternative, no remedial technologies would be implemented to reduce arsenic and benzene concentrations within deep surface water of the HBHA Pond. The alternative would not limit potential ecological exposures to contaminated surface water. This alternative does not reduce ecological risks nor prevent the downstream migration of arsenic contaminated sediments and would require the performance of 5-year reviews. A summary of ARARs associated with this alternative is presented on Tables 4-25A through 4-25C. The evaluation of this alternative against the NCP criteria is presented on Table 4-25D.

4.2.4.2 Alternative SW-2: Monitoring

Alternative SW-2 (Monitoring) is an alternative that involves no active treatment, but monitors the status of contamination that may or may not be attenuated by natural processes or other selected groundwater and sediment remedial alternatives. Although degradation of organic contaminants in the deeper surface water of the HBHA Pond is anticipated through natural processes, the degradation of arsenic is not expected unless the sources of contamination (i.e. groundwater discharges and arsenic dissolution from contaminated sediments) are eliminated through implementation of a plume intercept alternative and a sediment removal alternative that addresses the northern portion of the Pond. If contaminated groundwater discharges to the Pond are prevented and the existing sediment load in the northern portion of the Pond are removed, arsenic may be converted to a less bioavailable or toxic form, thereby reducing the impairment effects to aquatic organisms resulting from contaminated surface water.

As such, this alternative would not be fully protective of the environment (i.e. aquatic organisms) unless implemented in conjunction with other media-specific alternatives whereby the sources of contamination (i.e. groundwater discharges and arsenic dissolution from contaminated sediments) are eliminated.

A summary of ARARs associated with this alternative is presented on Tables 4-26A through 4-26C. The evaluation of this alternative against the NCP criteria is presented on Table 4-26D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop monitoring requirements;
- Mobilization and demobilization of required personnel and equipment to the site to conduct periodic sampling of surface water, and perform toxicity testing, and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.2.4.3 Alternative SW-3: Monitoring and Providing an Alternate Habitat

The monitoring component of Alternative SW-3 (Monitoring and Providing an Alternate Habitat) is identical to that which is included in Alternative SW-2. As discussed above, unless the sources of contamination (i.e. contaminated groundwater and sediments) are addressed through other media-specific alternatives, natural processes are not expected to attenuate contaminants to concentrations that do not reflect impairment to aquatic organisms. To mitigate the loss of aquatic habitat within the affected area (see Figure 2-6) and meet the RAO, a similar wetland would be constructed to compensate for the loss and to maintain the inventory of the benthic community within the watershed.

A summary of ARARs associated with this alternative is presented on Tables 4-27A through 4-27C. The evaluation of this alternative against the NCP criteria is presented on Table 4-27D. The primary components of this alternative would include:

- Coordination with local, state, and federal agencies and property owners to develop monitoring requirements and design the compensatory wetland;
- Conduct studies to locate the compensatory wetland ;
- Acquisition of land for the compensatory wetland;
- Mobilization and demobilization of required personnel and equipment to the site to conduct property surveys, construct the wetlands, and conduct periodic sampling;
- Construct the compensatory wetland
  - Clear and grub site;
  - Excavate to design grades;
  - Construct flow control structures;
  - Backfill with designed wetland substrates, and
  - Plant vegetation;
- Long-term monitoring of groundwater, surface water, and sediments to evaluate contaminant status and migration;
- Long-term monitoring and maintenance of compensatory wetland to ensure vegetation and biota are established; and
- Performance of 5-year reviews to evaluate site conditions and risks.

4.3 Comparative Analysis of Alternatives

This section presents an evaluation of the relative performance of each alternative, by medium, with regards to key elements of the seven NCP evaluation criteria. These criteria include:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume Through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

Comparisons were made between each alternative within a given medium for the specific criterion. These comparisons are discussed in the following sections and are summarized in Tables 4-28A through 4-28G.

4.3.1 Comparative Analysis of Surface Soil Alternatives

As part of the detailed analysis, this section presents an evaluation of the relative performance of each surface soil alternative with regards to seven of the nine NCP evaluation criteria and is used in the selection of a remedial alternative by evaluating the advantages and disadvantages of each alternative in comparison to the NCP criteria.

Surface soils did not pose any unacceptable risks to the environment. Consequently, only human health risks and hazards are specifically addressed by the selected remedial alternatives. However, the remedial activities may have a secondary benefit of further reducing potential environmental impacts caused by the migration or erosion of contaminated surface soils.

4.3.1.1 Overall Protection of Human Health and the Environment

Alternative SS-1 (No Action) offers no protection of human health or the environment because no actions would be taken at the site. RAOs would not be achieved with Alternative SS-1 (No Action).

Alternative SS-2 (Institutional Controls with Monitoring) would provide protection from exposure to contaminated soils provided that institutional controls are able to be adequately enforced. Currently, groundwater conditions at this area do not pose a risk or hazard to human health or a risk to the environment. Monitoring would ensure that groundwater conditions are periodically evaluated to determine if these conditions change as a result of the contaminated soils that would be left in-place.

Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) would provide enhanced protection over SS-2 since a permeable cover or barrier would further restrict exposure to the soils, provided the barrier is not breached from activities such as construction excavations. Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) is similar to the soil remedial alternative selected under the 1986 OU-1 ROD for Industri-plex. Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) would also require institutional controls in order to protect the integrity of the cover by providing for long-term maintenance and restrictions on land use and monitoring to evaluate changes to groundwater conditions potentially resulting from soil impacts.

Alternative SS-4 (Excavation and Off-Site Disposal) and Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) provide the highest level of protection to human health (and the environment) because all contamination exceeding the specified PRG would either be removed from the site or treated to remove the contaminant, and reused as backfill.

4.3.1.2 Compliance with ARARs

Risk-based PRGs were developed based on human health risk guidance and other TBC advisories. Alternative SS-1 (No Action) would not comply with these TBCs.

Alternatives SS-2 (Institutional Controls with Monitoring), SS-3 (Permeable Cover with Institutional Controls), SS-4 (Excavation and Off-Site Disposal), and Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) would comply with all ARARs and TBCs.

4.3.1.3 Long-Term Effectiveness and Permanence

Alternative SS-1 (No Action) does not provide any long-term effectiveness or permanence. Alternative SS-2 (Institutional Controls with Monitoring) would provide long-term effectiveness and permanence provided that institutional controls include enforceable, deeded, land-use restrictions or other appropriate institutional controls. This alternative would require periodic inspections to ensure that the institutional controls are adequate to achieve RAOs.

Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) would also provide long-term effectiveness and permanence providing the permeable cover is not breached. As with Alternative SS-2 (Institutional Controls with Monitoring), the magnitude of residual risk would be moderate since Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) requires institutional controls that include enforceable, deeded, land-use restrictions or other appropriate institutional controls and inspections by regulatory authorities to ensure that the institutional controls are remaining in effect. The reliability of institutional controls is dependent upon the degree of regulatory enforcement through inspections, oversight, and taking additional measures as necessary.

Alternatives SS-4 (Excavation and Off-Site Disposal) and SS-5 (Excavation, Treatment, and On-Site Reuse) provide the highest degree of long-term effectiveness and permanence because the contaminants would be completely removed from the site. If, however, pre-design investigations determine that soil contamination exists under building foundations that exceed the PRG, then institutional controls would be required for soils under the building until such time that the contaminated soils are removed, for example following building demolition. The magnitude of residual risks in Alternatives SS-4 (Excavation and Off-Site Disposal) and SS-5 (Excavation, Treatment, and On-Site Reuse) would be low.

4.3.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative SS-1 (No Action), Alternative SS-2 (Institutional Controls with Monitoring), and Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) would not provide any treatment of contaminants.

Alternative SS-4 (Excavation and Off-Site Disposal) may provide limited off-site treatment, if necessary to qualify for land disposal at a licensed landfill.

Only Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) provides for the reduction of toxicity and mobility of the contaminants through treatment by using acid extraction to remove arsenic from the soils. Volume is not affected since the “cleaned” soils will be reused as backfill. Concentrated arsenic-contaminated rinsate from the acid extraction process would require off-site treatment and disposal.

4.3.1.5 Short-Term Effectiveness

Because Alternative SS-1 (No Action) would not require any action, there would be no short-term impacts to the community or to onsite workers. Since no onsite actions are required under Alternative SS-2 (Institutional Controls), there would be no impacts to the community or to workers. Although Alternative SS-2 (Institutional Controls with Monitoring) would not have health-related impacts to the community or workers, it would have some limited impacts to property owners since the imposition of institutional controls would restrict land use and require property owners to maintain otherwise unrestricted open land.

Alternative SS-3 (Permeable Cover with Institutional Controls), Alternative SS-4 (Excavation and Off-Site Disposal), and Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) would have the most short-term impacts on the community. Impacts to workers would be minimal since construction activities would be completed in accordance with appropriate health and safety procedures. Potential risks and hazards associated with fugitive dust emissions would be addressed with prescribed engineering controls. No adverse environmental impacts are anticipated from any alternative. Other non-health related impacts would result from inconveniences in traffic control during construction and/or excavation activities.

Alternative SS-2 (Institutional Controls with Monitoring) and Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) may take the longest to implement due to potential delays associated with inaugurating the actual institutional controls and deed attachment documents. Alternative SS-4 (Excavation and Off-Site Disposal) and Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) would take the shortest time to implement and achieve the RAOs.

RAOs for protection of human health would be achieved as soon as the institutional controls are implemented for Alternative SS-2 (Institutional Controls with Monitoring) and SS-3 (Permeable Cover with Institutional Controls) as well as its installation of the permeable cover, and upon completion and removal (and/or treatment) of soils for Alternative SS-4 (Excavation and Off-Site Disposal) and Alternative SS-5 (Excavation, Treatment, and On-Site Reuse).

4.3.1.6 Implementability

Alternative SS-1 (No Action) would be the easiest to implement because there are no remedial actions required.

Alternative SS-2 (Institutional Controls with Monitoring) would be the next easiest to implement. Although, as discussed above, potential delays may be encountered with the inauguration of the actual institutional controls and deed attachment documents.

Alternative SS-3 (Permeable Cover with Institutional Controls), Alternative SS-4 (Excavation and Off-Site Disposal), and Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) would be more difficult than the other alternatives due to the number of additional construction tasks required and the potential construction coordination problems. These additional tasks are basic construction methods and procedures that involve survey, excavation, and backfill. Installation of a permeable cover, such as a geotextile, does not necessarily require special skills whereby the availability of trained or specialized personnel would be limited.

4.3.1.7 Cost

The overall cost for each alternative is based upon the initial capital cost to construct the remedy and the annual operation and maintenance costs to maintain the integrity of the remedy over 30 years. Using a seven percent discount factor, the total remedy costs over a 30-year period are then calculated in a present-worth analysis.

Since no action is required for Alternative SS-1 (No Action), no costs would be incurred. Present-worth values for other alternatives are estimated as follows:

- Alternative SS-2 (Institutional Controls with Monitoring) $ 600,000
- Alternative SS-3 (Permeable Cover and Monitoring with Institutional Controls) $ 5,992,000
- Alternative SS-4 (Excavation and Off-Site Disposal) $47,172,000
- Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) $22,993,000

Costs for Alternative SS-3 (Permeable Cover with Institutional Controls), Alternative SS-4 (Excavation and Off-Site Disposal), and Alternative SS-5 (Excavation, Treatment, and On-Site Reuse) are volume dependent. These costs could vary significantly (plus or minus) depending on the actual limits of contamination exceeding the PRGs. The limits of contamination assumed for this FS are based upon widely spaced data. Additional studies should be performed prior to completing the final remedial design to delineate the extent of remediation required.

4.3.2 Comparative Analysis of Subsurface Soil Alternatives

As part of the detailed analysis, this section presents an evaluation of the relative performance of each subsurface soil alternative with regards to seven of the nine NCP evaluation criteria and is used in the selection of a remedial alternative by evaluating the advantages and disadvantages of each alternative in comparison to the NCP criteria.

Subsurface soils did not pose any unacceptable risks to the environment. Consequently, only human health risks and hazards are specifically addressed by the selected remedial alternatives. However, the remedial activities may have a secondary benefit of further reducing potential environmental impacts caused by the migration and erosion of contaminated subsurface soils such as potential impacts to groundwater.

4.3.2.1 Overall Protection of Human Health and the Environment

Alternative SUB-1 (No Action) would offer no protection of human health or the environment because no actions would be taken at the site. RAOs would not be achieved with Alternative SUB-1 (No Action).

Alternative SUB-2 (Institutional Controls with Monitoring) would provide protection from exposure to contaminated soils provided that institutional controls are able to be adequately enforced. Due to the fact that subsurface soils are located at least 3 feet below ground surface, the likelihood that institutional controls would be an effective deterrent to human exposures to contamination is very high.

Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) would provide slightly enhanced protection, since a permeable cover or barrier would further restrict exposure to subsurface soils, provided the barrier is not breached from activities such as construction excavations. However, since subsurface soil is located at least 3 feet below the ground surface, the marginal benefit provided by a permeable cover with institutional controls (Alternative SUB-3) over institutional controls only (Alternative SUB-2) would be low since subsurface soil has limited accessibility even without the cover.

Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) is similar to the soil remedial alternative selected under the 1986 OU-1 ROD for Industri-plex. Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) would also require institutional controls in order to protect the integrity of the cover by providing for long-term maintenance and land-use restrictions or other appropriate institutional controls.

4.3.2.2 Compliance with ARARs

Risk-based PRGs were developed based on human health risk guidance and other TBC advisories. Alternative SUB-1 (No Action) does not comply with these TBCs.

Alternatives SUB-2 (Institutional Controls with Monitoring) and SUB-3 (Permeable Cover with Institutional Controls), would however, comply with all applicable ARARs and TBCs.

4.3.2.3 Long-Term Effectiveness and Permanence

Alternative SUB-1 (No Action) does not provide any long-term effectiveness or permanence and the magnitude of residual risk would be high. Alternative SUB-2 (Institutional Controls with Monitoring) would provide long-term effectiveness and permanence provided that institutional controls include enforceable, deeded, land-use restrictions or other appropriate institutional controls. This alternative would require inspections to ensure that the institutional controls are remaining in effect.

Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) would also provide long-term effectiveness and permanence providing the permeable cover is not breached. As with Alternative SUB-2 (Institutional Controls with Monitoring), Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) requires institutional controls that include enforceable, deeded, land-use restrictions or other appropriate institutional controls and inspections to ensure that the institutional controls are remaining in effect. Consequently, the magnitude of residual risk for Alternative SUB-2 (Institutional Controls with Monitoring) and Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) would be similar.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative SUB-1 (No Action) and Alternative SUB-2 (Institutional Controls with Monitoring) would not provide any reduction in the toxicity, mobility, or volume of contaminants through treatment. Under Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls), limited off-site treatment of soil may be necessary to qualify for land disposal at a licensed landfill.

4.3.2.5 Short-Term Effectiveness

Because Alternative SUB-1 (No Action) would not require any action, there would be no short-term impacts to the community or to onsite workers. Since no onsite actions are required under Alternative SUB-2 (Institutional Controls with Monitoring), there would be no impacts to the community or to workers. Alternative SUB-2 (Institutional Controls with Monitoring) would not have any health related impacts to the community or workers, but would have some limited impacts to property owners since the imposition of institutional controls would restrict land use and require property owners to maintain otherwise unrestricted open land.

Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) would have the most significant short-term impacts on the community. Impacts to workers would be minimal since construction activities would be completed in accordance with appropriate health and safety procedures. Potential risks and hazards associated with fugitive dust emissions would be addressed with prescribed engineering controls. No adverse environmental impacts are anticipated from any alternative. Other non-health related impacts would result from inconveniences in traffic control during construction and/or excavation activities. Impacts to individual property owners would be significant since large portions of property would require a soil cover and use of parking areas or property access would be temporarily restricted. No adverse environmental impacts are anticipated from any alternative.

Alternative SUB-2 (Institutional Controls with Monitoring) and Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) may take the longest to implement due to potential delays associated with inaugurating the actual institutional controls and deed attachment documents. Alternative SUB-3 (Permeable Cover and Monitoring with Institutional

Controls) would take the longest to implement from a construction schedule since it is the only alternative that includes onsite actions.

RAOs for protection of human health would be achieved as soon as the institutional controls are implemented for Alternative SUB-2 (Institutional Controls with Monitoring) and Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) as well as the installation of permeable cover.

4.3.2.6 Implementability

Alternative SUB-1 (No Action) would be the easiest to implement because there are no remedial actions required.

Alternative SUB-2 (Institutional Controls with Monitoring) would be the next easiest to implement. Although, as discussed above, potential delays may be encountered with the inauguration of the actual institutional controls and deed attachment documents.

Alternative SUB-3 (Permeable Cover with Institutional Controls), would be the most difficult of the subsurface soil alternatives to implement due to the area requiring remediation, the proximity of those areas to active commercial and light industrial properties, and the additional construction tasks associated with the work. As with the surface soil alternatives, these additional tasks are basic construction methods and procedures that involve survey, excavation, and backfill. Installation of a permeable cover, such as a geotextile, does not necessarily require special skills whereby the availability of trained or specialized personnel would be limited.

4.3.2.7 Cost

The overall costs for each alternative are based upon initial capital costs to construct the remedy and the annual operation and maintenance costs to maintain the integrity of the remedy over 30 years. Using a seven percent discount factor, the total remedy costs over a 30-year period are then calculated in a present-worth analysis.

Since no action is required for Alternative SUB-1 (No Action), no costs would be incurred. Present-worth values for Alternative SUB-2 (Institutional Controls with Monitoring) and Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) are estimated as follows:

- Alternative SUB-2 (Institutional Controls with Monitoring) $1,276,000
- Alternative SUB-3 (Permeable Cover with Institutional Controls) $8,070,000

The cost for Alternative SUB-3 (Permeable Cover and Monitoring with Institutional Controls) is volume dependent. This cost could vary significantly (plus or minus) depending on the actual limits of contamination exceeding the PRGs. The limits of contamination assumed for this FS are based upon widely spaced data. Additional studies should be performed prior to completing the final remedial design to delineate the extent of remediation required.

4.3.3 Comparative Analysis of Groundwater Alternatives

As part of the detailed analysis, this section presents an evaluation of the relative performance of each groundwater alternative with regards to seven of the nine NCP evaluation criteria and is used in the selection of a remedial alternative by evaluating the advantages and disadvantages of each alternative in comparison to the NCP criteria.

4.3.3.1 Overall Protection of Human Health and the Environment

Alternative GW-1 (No Action) would offer no protection of human health or the environment because no actions would be taken at the site. RAOs would not be achieved with GW-1 (No Action).

Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) would provide protection of human health from exposure to contaminated groundwater through institutional controls, provided that institutional controls are able to be adequately enforced. However, groundwater discharge to the HBHA Pond would continue to impact sediments and surface water, offering no protection to the environment unless this alternative is implemented in conjunction with another media-specific alternative that prevents the transport of contaminated sediment from the Pond to downstream depositional areas, such as Alternative HBHA-4 (Storm

Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat).

Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would also provide protection of human health from exposure to contaminated groundwater through the use of institutional controls. Since contaminant concentrations in groundwater within the treatment zone would not be expected to decrease below PRGs within the foreseeable future, the level of human health protection provided by these alternatives would be similar to that provided by Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls), and would depend upon the enforcement of controls. Alternatives GW-3 and Alternative GW-4 would provide enhanced protection of the environment over Alternative GW-2, since these alternatives would eliminate contaminated groundwater discharges to the HBHA Pond.

4.3.3.2 Compliance with ARARs

Risk-based PRGs were developed based on human health risk guidance and other TBC advisories. Alternative GW-1 (No Action) does not comply with these TBCs.

Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls), Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring), and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would comply with all applicable ARARs and TBCs, provided that institutional controls restricting Site groundwater use are able to be adequately enforced. Institutional controls also include provisions to provide worker safety if excavations into groundwater are required during construction activities.

Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) may not comply with the chemical-specific ARAR regarding federal or state ambient water quality criteria for the protection of surface water unless Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) were selected. In this case, Alternative GW-2 would comply with the chemical-specific ARARs at the point of compliance, which is defined as the downstream side of the cofferdams.

Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would comply with all applicable ARARs and TBCs.

4.3.3.3 Long-Term Effectiveness and Permanence

Alternative GW-1 (No Action) does not provide any long-term effectiveness or permanence.

Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) would provide long-term effectiveness and permanence provided that institutional controls include enforceable, deeded, land-use restrictions, or other appropriate institutional controls. However, since no actions would be taken, the residual risks would be moderate, unless another alternative such as HBHA-4 were to be implemented in conjunction with this alternative. This alternative would also include inspections to ensure that the institutional controls are remaining in effect. Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) would not be effective in controlling groundwater discharges to the HBHA Pond.

The magnitude of residual risk to the environment for Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would be moderate since contaminated groundwater discharges to the HBHA Pond would be eliminated, but impacts to site-wide groundwater would remain. As with Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls), these alternatives rely on institutional controls to offer protection to human health and would not take actions to reduce arsenic contamination site-wide. Contamination by organic compounds (benzene, TCE, 1,2-DCA, and naphthalene) would be addressed.

The treatment technologies for Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) have been historically proven to be effective, but require more extensive operation and maintenance than an in-situ system as described for Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring). Alternative GW-4 (Plume Intercept by In-Situ

Groundwater Treatment with Institutional Controls and Monitoring) would require more extensive monitoring to ensure that the reactive wall is effective in containing and treating the contaminant plume and to ensure that in-situ oxidants are effectively degrading organic compounds.

4.3.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative GW-1 (No Action) offers no treatment other than long-term benefits achieved from natural attenuation processes that may occur with organic contaminants. Similarly, Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) offers no treatment other then long-term benefits from natural attenuation processes that may occur with organic contaminants, but improves the control of contaminated groundwater migration via pond intercept and monitoring.

Both Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) are similar in that they both employ technologies to prevent contaminated groundwater from discharging into the HBHA Pond and destroy or remove target contaminants from groundwater. Alternative GW-3 is an ex-situ system while Alternative GW-4 is an in-situ design. Both technologies are capable of removing contaminants to below the respective contaminant’s PRG prior to their discharge to the HBHA Pond. The toxicity, mobility and volume of contaminants would be removed from groundwater and both treatment processes are irreversible.

None of the above alternatives would be capable of treating site-wide inorganic (e.g. arsenic) contaminated groundwater to concentrations below the PRG due to wide spread arsenic contamination sources in soils that will continue to impact groundwater at the Industri-plex Site. Alternatives GW-2 (Pond Intercept and Monitoring with Institutional Controls), GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) intercept contaminated groundwater to control downgradient migration, and do not address site-wide inorganic contaminated groundwater except for the protection of human health through the use of institutional controls.

4.3.3.5 Short-Term Effectiveness

Because Alternative GW-1 (No Action) would not require any action, there would be no short-term impacts to the community or to onsite workers. Since no onsite actions are required under Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls), there would be no impacts to the community or to workers. Alternative GW-2 would have limited non-health related impacts to property owners since the imposition of institutional controls would restrict groundwater use.

Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would have limited short-term impacts on the community. Potential risks due to contamination to the community and site workers would be minimal and easily controlled through engineering controls and safety procedures. Potential risks and hazards associated with fugitive dust emissions would be addressed with prescribed engineering controls. Other potential non-health related impacts would be the results of inconveniences in traffic control during construction and/or excavation activities.

Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) may have limited adverse environmental impacts during construction. Again, engineering controls and approved construction methods would minimize these risks. Once constructed, other environmental risks associated with both alternatives would be the result of a failure to maintain the remedy causing contaminant discharges to the surface water.

Both Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge and Monitoring with Institutional Controls and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would require pre-design investigations to properly design the respective treatment system. Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) would take longer to construct than Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) due to the mechanical complexities of the treatment system. Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) would also likely require longer start-up times and pilot testing periods to calibrate and optimize the system performance.

Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls), Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring), and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would take equally as long to implement institutional controls as described above in other alternatives due to potential delays.

RAOs for protection of human health would be achieved as soon as the institutional controls are in place for Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls), Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring), and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring). RAOs for protection of the environment for surface water would be achieved for Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) and Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) as soon as construction is complete and the system is functional. RAOs for protection of the environment for Site-wide groundwater at Industri-plex due to arsenic contamination would not be achieved for any alternative. RAOs for protection of the environment for Site-wide groundwater at Industri-plex due to organic contamination would be achieved in several years following direct source application of the enhanced bioremediation technology.

4.3.3.6 Implementability

Alternative GW-1 (No Action) is the easiest to implement because there are no remedial actions required.

Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) would be the next easiest to implement. As discussed above, potential delays may be encountered with the inauguration of the actual institutional controls and deed attachment documents, but these delays would also impact the schedule for Alternatives GW-3 and GW-4, which would also require institutional controls to protect human health.

Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) would be more difficult to implement than Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) due to the complexities involved with constructing a multi-process treatment system and associated typical construction issues. However, construction of treatment systems is considered fairly routine involving skilled trade workers such as carpenters, pipe fitters, electricians, process engineers, etc. Technologies for Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) are reliable and proven. Numerous vendors are available to provide the equipment necessary for Alternative GW-3. Options for off-site treatment and disposal of process sludges generated are readily available. Alternative GW-3 requires more extensive operation and maintenance than any other alternative and would likely require a full-time treatment plant operator.

Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) would be the most difficult to implement due to the deep excavations required to install the reactive wall. If a funnel and gate approach is used, the barrier wall must be keyed into or at least sealed at the bedrock-overburden interface. Some uncertainty exists regarding the life-span of the reactive materials used in the wall due to the geochemical conditions in Site groundwater. Some uncertainty also exists as to the potential effectiveness and difficulties in delivering oxygenating reagents to a broad area for the remediation of the organic contaminants. However, these uncertainties may be overcome with a pre-design investigation that would identify a reasonable and practical spatial application design. Equipment and technical specialists required to implement Alternative GW-4 (Plume Intercept by In-Situ Groundwater Treatment with Institutional Controls and Monitoring) are available from several vendors. Options for off-site treatment and disposal of spent reactive wall materials generated are readily available.

4.3.3.7 Cost

The overall cost for each alternative is based upon initial capital cost to construct the remedy and the annual operation and maintenance costs to maintain the integrity of the remedy over 30 years. Using a seven percent discount factor, the total remedy costs over a 30-year period are then calculated in a present-worth analysis.

Since no action is required for Alternative GW-1 (No Action), no costs would be incurred. Present-worth values for other alternatives are estimated as follows:

- Alternative GW-2 (Pond Intercept and Monitoring with Institutional Controls) $ 3,918,000
- Alternative GW-3 (Plume Intercept by Groundwater Extraction, Treatment and Discharge with Institutional Controls and Monitoring) $18,943,000
- Alternative GW-4 (Plume Intercept, In-Situ Groundwater Treatment with Institutional Controls) $16,153,000

4.3.4 Comparative Analysis of HBHA Pond Sediment Alternatives

As part of the detailed analysis, this section presents an evaluation of the relative performance of each sediment alternative with regards to seven of the nine NCP evaluation criteria and is used in the selection of a remedial alternative by evaluating the advantages and disadvantages of each alternative in comparison to the NCP criteria.

HBHA Pond sediments do not pose risks and hazards in excess of regulatory criteria to human health. Consequently, only environmental risks are specifically addressed by the selected remedial alternatives. However, the remedial activities may have a secondary benefit of further reducing potential human health risks and hazards resulting from the migration of contaminated sediments to downstream depositional areas that are accessible to humans.

4.3.4.1 Overall Protection of Human Health and the Environment

There are no human health risks and hazards in excess of regulatory criteria associated with sediments in the HBHA Pond. All unacceptable sediment risks are associated with impairment to benthic organisms.

Alternative HBHA-1 (No Action) offers no protection to the environment because no actions would be taken at the site. RAOs would not be achieved with HBHA-1.

In the short-term Alternative HBHA-2 (Monitoring) would not provide protection to the environment unless it is implemented in conjunction with a groundwater alternative to eliminate contaminated groundwater discharges into the HBHA Pond. If contaminated groundwater is prevented from discharging into the HBHA Pond, then long-term organic sediment contamination may be biodegraded and inorganic sediments may be buried by uncontaminated sediments. If contaminated groundwater continues to discharge into the HBHA Pond, then inorganic contaminated sediments will remain, while organic sediment contamination may be further degraded through natural biological processes.

Alternative HBHA-3 (Subaqueous Cap) may provide enhanced protection since a subaqueous cap (permeable cover or barrier) would be installed protecting benthic organisms from exposure to the contaminated sediments and providing a new benthic habitat. However, Alternative HBHA-3 (Subaqueous Cap) requires that groundwater discharges be eliminated, otherwise the cap materials could become re-contaminated.

Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) would provide protection to benthic organisms in the southern portion of the HBHA Pond where contaminated sediments are removed. Since the northern portion of the pond would be used as a treatment area for contaminated groundwater discharges, this northern area would not provide protection to the benthic organisms in the short-term. However, Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) would provide an alternate habitat to compensate for this loss and would maintain the benthic community inventory within the watershed. In the long-term, if groundwater contamination is prevented from discharging into the HBHA Pond, then sediments may recover as discussed for Alternative HBHA-2 (Monitoring). If groundwater contamination continues to discharge into the HBHA Pond, then sediment contamination by organic compounds may be reduced through biodegradation as discussed for Alternative HBHA-2 (Monitoring).

Alternative HBHA-5 (Removal and Off-Site Disposal) provides the highest level of protection for the environment because all contamination exceeding the PRGs would be removed from the HBHA Pond. However, as with the other HBHA sediment alternatives, Alternative HBHA-5

(Removal and Off-Site Disposal) relies on the elimination of contaminated groundwater discharges so that the remediated areas are not re-contaminated.

4.3.4.2 Compliance with ARARs

Alternative HBHA-1 (No Action) and Alternative HBHA-2 (Monitoring) would not comply with chemical-specific or action-specific ARARs related to federal or state ambient water quality criteria for the protection of surface water since there would be no actions taken to abate sediment contamination which would likely continue to degrade surface water quality. There are no location-specific ARARs that were identified for Alternative HBHA-1 (No Action) or Alternative HBHA-2 (Monitoring).

Alternative HBHA-3 (Subaqueous Cap), Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat), and Alternative HBHA-5 (Removal and Off-Site Disposal) would comply with all applicable ARARs and TBCs.

HBHA-4 is the only practicable alternative that achieves the project purpose of reducing environmental risk. The alternatives HBHA-1 (No Action) and HBHA-2 (Monitoring) don't reduce the risk. Alternative HBHA-5 (Removal and Off-Site Disposal) where removal of contaminated sediment in the entire pond would initially reduce ecological risk, but the area would become recontaminated through groundwater discharge and ultimately would not achieve the project purpose. Given that contaminated groundwater will continue to flow towards the pond, the LEDPA that achieves the project purpose is HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat), which divides the pond into the northern area, which will become recontaminated and require periodic dredging, and the southern area, which will be remediated. Compensatory mitigation will be required for the impacts to the northern area of the pond.

4.3.4.3 Long-Term Effectiveness and Permanence

Alternative HBHA-1 (No Action) does not provide any long-term effectiveness or permanence.

Alternative HBHA-2 (Monitoring) would provide marginal long-term effectiveness and permanence since the magnitude of risk would not be reduced in the short-term or long-term unless other alternatives were implemented to eliminate contaminated groundwater discharges. Long-term monitoring would be required to evaluate risks associated with the residual contamination left in-place.

Alternative HBHA-3 (Subaqueous Cap) would provide enhance long-term effectiveness and permanence provided that the permeable cover is not eroded and arsenic does not diffuse from the contaminated sediments and contaminate the cap materials and providing that the contaminated groundwater discharges are eliminated. Long-term monitoring and maintenance would be required to ensure the integrity of the cap.

The magnitude of residual risks associated with Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) would be less than Alternative HBHA-3 (Subaqueous Cap) since the majority of contaminated sediments would be removed from the HBHA Pond (southern portion). Long-term maintenance would be required to periodically remove accumulated sediments in the retention area (northern portion) and monitoring of surface water to evaluate risks from residual contaminated sediments left in-place. An alternate or compensatory wetland habitat would be constructed to mitigate the wetland loss due to the creation of the sediment retention area. Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) does not rely on the elimination of groundwater discharges as do the other alternatives evaluated.

Alternative HBHA-5 (Removal and Off-Site Disposal) provides the highest level of long-term effectiveness and permanence because the contaminants would be completely removed from the HBHA Pond and the magnitude of residual risk would be minimal, assuming that contaminated groundwater discharges are eliminated.

4.3.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative HBHA-1 (No Action), Alternative HBHA-2 (Monitoring), and Alternative HBHA-3 (Subaqueous Cap) do not provide any treatment of contaminants.

Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) and Alternative HBHA-5 (Removal and Off-Site Disposal) may provide for limited off-site treatment of dredged sediments if necessary to qualify for land disposal at a licensed landfill.

Alternative HBHA-3 (Subaqueous Cap) reduces the mobility of contaminated sediments by placing a cap over them. Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) also reduces the mobility of contaminated sediments by creating a retention area for sediment to be contained and periodically removed.

The volume of contaminated sediments is not affected by any onsite treatment process for any alternative.

4.3.4.5 Short-Term Effectiveness

Because Alternative HBHA-1 (No Action) would not require any action, there would be no short-term impacts to the community or to onsite workers. Since Alternative HBHA-2 (Monitoring) only requires monitoring, there would be no impacts to the community. Potential impacts to workers would be addressed by implementing appropriate health and safety plans.

Alternative HBHA-3 (Subaqueous Cap), Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat), and Alternative HBHA-5 (Removal and Off-Site Disposal) would have the most short-term impacts on the community. Potential risks associated with fugitive dust emissions would be addressed with prescribed engineering controls. Impacts to workers would be minimal since construction activities would be completed in accordance with appropriate health and safety procedures. Other non-health related impacts would result from inconveniences in traffic control during construction and/or excavation activities.

Alternative HBHA-1 (No Action) would have no adverse environmental impacts. Alternative HBHA-2 (Monitoring) would have minor environmental impacts due to workers collecting environmental samples. Alternative HBHA-3 (Subaqueous Cap) would have potential significant environmental impacts from the displacement and migration of contaminated sediments during cap placement. However, these potential risks could be minimized through engineering controls and the use of specialized construction methods to minimize and control suspended solids.

Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) and Alternative HBHA-5 (Removal and Off-Site Disposal) would have the most significant short-term environmental impacts due to the dredging activities whereby the existing benthic community would be destroyed during remediation. In time, new benthic communities would be established within the replacement substrate.

4.3.4.6 Implementability

Alternative HBHA-1 (No Action) would be the easiest to implement because there are no remedial actions required. Alternative HBHA-2 (Monitoring) would be the next easiest since only the collection of environmental samples is involved.

Alternative HBHA-3 (Subaqueous Cap), Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat), and Alternative HBHA-5 (Removal and Off-Site Disposal) would be much more difficult than Alternatives HBHA-1 and HBHA-2 due to the number of additional tasks required. These additional tasks are specialized construction methods and procedures that involve working on a surface water body and controlling of re-suspension of sediments. Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) and Alternative HBHA-5 (Removal and Off-Site Disposal) would be more difficult because construction activities would include hydraulic dredging, water treatment, and sediment dewatering. Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) is more difficult than Alternative HBHA-5 (Removal and Off-Site Disposal) because it is further compounded by the construction of a sediment retention area and an alternate/compensatory wetland habitat.

Alternative HBHA-3 (Subaqueous Cap) would likely be the most difficult due to the uncertainty in controlling the displacement of the low-specific gravity sediments that are unique to HBHA Pond without causing extensive contaminant migration or contamination of the cap materials. Alternative HBHA-3 (Subaqueous Cap), HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat), and Alternative HBHA-5 (Removal and Off-Site Disposal) require specialized equipment and skilled workers, all of which are readily available from several vendors.

Alternative HBHA-3 (Subaqueous Cap) and Alternative HBHA-5 (Removal and Off-Site Disposal) would achieve the RAO as soon as the construction of the cap or dredging and restoration is complete.

All alternatives except HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) require that contaminated groundwater discharges be eliminated prior to constructing the remedy otherwise each remediated area would likely be re-contaminated.

4.3.4.7 Cost

The overall cost for each alternative is based upon the initial capital cost to construct the remedy and the annual operation and maintenance costs to maintain the integrity of the remedy over 30 years. Using a seven percent discount factor, the total remedy costs over a 30-year period are then calculated in a present-worth analysis.

Since no action is required for Alternative HBHA-1 (No Action), no costs would be incurred. Present-worth values for other alternatives are estimated as follows:

- Alternative HBHA-2 (Monitoring) $1,201,000
- Alternative HBHA-3 (Subaqueous Cap) $5,291,000
- Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) $8,237,000
- Alternative HBHA-5 (Removal and Off-Site Disposal) $3,810,000

It should be noted that the cost for Alternative HBHA-4 (Storm Water Bypass and Sediment Retention with Partial Dredging and Providing an Alternate Habitat) assumes that the sediment retention area would require periodic dredging to remove accumulated sediments once every five years. These costs could be more or less depending on the frequency of sediment removal, which would be based on actual sediment accumulation rates. Also, the cost for habitat replacement assumes that land is available within the watershed to construct an alternate/compensatory wetland. Land acquisition costs are assumed to be approximately $700,000 per acre and could be more or less depending on the location selected.

4.3.5 Comparative Analysis of Near Shore Sediment Alternatives

As part of the detailed analysis, this section presents an evaluation of the relative performance of each sediment alternative with regards to seven of the nine NCP evaluation criteria and is used in the selection of a remedial alternative by evaluating the advantages and disadvantages of each alternative in comparison to the NCP criteria. Near shore sediments did not pose any unacceptable risks to the environment. Only human health risks and hazards are addressed by the selected remedial alternatives.

4.3.5.1 Overall Protection of Human Health and the Environment

Alternative NS-1 (No Action) offers no protection of human health because no actions would be taken at the site. RAOs would not be achieved with Alternative NS-1 (No Action).

Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls) would provide protection of human health from exposure to contaminated sediments provided that institutional controls are able to be adequately enforced and protective fencing and signage are maintained. In addition to institutional controls, Alternative NS-3 (Monitoring with Institutional Controls) would also include monitoring to periodically evaluate the mitigation of potential sediment risks and hazards resulting from natural recovery processes that may occur, including burial of the contaminated sediments by accumulation of uncontaminated sediments if surface water and sediment inorganic contaminants from upstream are sufficiently controlled/ eliminated.

Alternative NS-4 (Removal and Off-Site Disposal) provides the highest level of protection for human health because all contamination exceeding the PRG would be removed from the near-shore sediment remediation areas.

4.3.5.2 Compliance with ARARs

Alternative NS-1 (No Action), Alternative NS-2 (Institutional Controls), and Alternative NS-3 (Monitoring with Institutional Controls) may not comply with action-specific or chemical-specific ARARs related to federal or state ambient water quality criteria for the protection of surface water since there would be no actions taken to abate sediment contamination which may degrade surface water quality. Alternative NS-1 (No Action) would not comply with PRGs, which were developed using TBC guidance for the development of risk-based remediation goals.

As long as the institutional controls are enforced and fencing is maintained, Alternative NS-2 (Institutional Controls), and Alternative NS-3 (Monitoring with Institutional Controls) would comply with chemical-specific TBCs by restricting access to contaminated, near shore sediments.

Alternative NS-4 (Removal and Off-Site Disposal) would comply with all applicable ARARs and TBCs.

4.3.5.3 Long-Term Effectiveness and Permanence

Alternative NS-1 (No Action) does not provide any long-term effectiveness or permanence. Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls) would provide long-term effectiveness and permanence provided that institutional controls include enforceable, deeded, land-use restrictions or other appropriate institutional controls. This alternative would require inspections to ensure that the institutional controls are remaining in effect.

The magnitude of residual risk would be highest for Alternative NS-1 (No Action) since no actions are taken. The magnitude of residual risk for Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls) would also be high because no direct action is being taken to reduce contamination within the sediments. Although institutional controls and fencing will be in-place to restrict access, these methods are only considered somewhat reliable depending upon the extent of enforcement and maintenance.

Alternative NS-4 (Removal and Off-Site Disposal) provides the best option for long-term effectiveness and permanence because the sediments exceeding the arsenic PRG would be completely removed from the site and the resulting magnitude of residual risk would be low.

4.3.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative NS-1 (No Action), Alternative NS-2 (Institutional Controls), and Alternative NS-3 (Monitoring with Institutional Controls) do not provide any treatment of contaminants. Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls), in the long-term, may realize some benefits from a reduction in mobility if contaminated sediments are buried by the accumulation of uncontaminated sediments through deposition.

The toxicity, mobility, and volume of contaminants would be reduced under Alternative NS-4 (Removal and Off-Site Disposal), since liquids resulting from the dewatering process would be treated to remove contaminants prior to discharge back to the environment. This alternative may also provide for limited off-site treatment to remove contaminants if required to qualify for land disposal at a licensed landfill.

4.3.5.5 Short-Term Effectiveness

Because Alternative NS-1 (No Action) would not require any action, there would be no short-term impacts to the community or to on-site workers. Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls) would have minor potential impacts to the community and to workers installing protective fencing. Other non-health related impacts include access restrictions and the imposition of institutional controls, which would further restrict land use and require property owners to maintain otherwise unrestricted open land.

Alternative NS-4 (Removal and Off-Site Disposal) would have the most short-term impacts on the community. Other non-health related impacts would result from inconveniences in traffic control during construction. Impacts to workers would be minimal since construction activities would be completed in accordance with appropriate health and safety procedures.

No adverse environmental impacts are anticipated from Alternative NS-1 (No Action), Alternative NS-2 (Institutional Controls), and Alternative NS-3 (Monitoring with Institutional Controls). Short-term environmental impacts would be caused by Alternative NS-4 (Removal and Off-Site Disposal) during construction of haul roads, excavation and dewatering of sediments, and restoration of the wetland areas. These impacts would be minimized by engineering controls and specialized construction methods during the remediation.

Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls) may take the longest to implement due to the delays associated with inaugurating the actual institutional controls and deed attachment documents. Alternative NS-4 (Removal and Off-Site Disposal) would take the shortest time to achieve the RAO, since it would not rely upon institutional controls to achieve human health protection.

4.3.5.6 Implementability

Alternative NS-1 (No Action) would be the easiest to implement because there are no remedial actions required. Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls) would be only slightly more difficult to implement, since only protective fencing and signage is required for onsite activities. Alternative NS-3 (Monitoring with Institutional Controls) would also include periodic sampling of surface water and sediment. As discussed above, institutional controls may be more difficult to complete due to potential delays that may be encountered with the inauguration of the actual institutional controls and deed attachment documents.

Alternative NS-4 (Removal and Off-Site Disposal) would be the most difficult to implement due to the number of additional tasks required. These additional tasks include excavation and dewatering of wetland sediments, excavation dewatering, water treatment, and restoration of a wetland area. The specialized equipment and skilled labor required to perform the work are readily available from several vendors.

RAOs for protection of human health would be achieved as soon as the institutional controls are implemented for Alternative NS-2 (Institutional Controls) and Alternative NS-3 (Monitoring with Institutional Controls), and upon completion and removal of contaminated sediments under Alternative NS-4 (Removal and Off-Site Disposal).

4.3.5.7 Cost

The overall cost for each alternative is based upon initial capital costs to construct the remedy and the annual operation and maintenance costs to maintain the integrity of the remedy over 30 years. Using a seven percent discount factor, the total remedy costs over a 30-year period are then calculated in a present-worth analysis.

Since no action is required for Alternative NS-1 (No Action), no costs would be incurred. Present-worth values for other alternatives are estimated as follows:

- Alternative NS-2 (Institutional Controls) $ 338,000
- Alternative NS-3 (Monitoring with Institutional Controls) $1,807,000
- Alternative NS-4 (Removal and Off-Site Disposal) $3,247,000

The cost for Alternative NS-4 (Removal and Off-Site Disposal) is volume dependent. This cost could vary significantly (plus or minus) depending on the actual limits of contamination exceeding the PRGs. The limits of contamination assumed for this FS are based upon widely spaced data, and additional studies should be performed prior to completing the final remedial design to more accurately delineate the extent of remediation required.

4.3.6 Comparative Analysis of Deep Sediment Alternatives

As part of the detailed analysis, this section presents an evaluation of the relative performance of each sediment alternative with regards to seven of the nine NCP evaluation criteria and is used in the selection of a remedial alternative by evaluating the advantages and disadvantages of each alternative in comparison to the NCP criteria. Deep sediments did not pose any unacceptable risks to the environment. Only potential human health risks and hazards are addressed by the selected remedial alternatives.

4.3.6.1 Overall Protection of Human Health and the Environment

Alternative DS-1 (No Action) offers no protection of human health because no actions would be taken at the site. RAOs would not be achieved with Alternative DS-1 (No Action).

Alternative DS-2 (Monitoring with Institutional Controls) would provide protection from exposure to contaminated sediments provided that institutional controls are able to be adequately enforced. The degree of protection that would be provided by this alternative would be high, since deep sediments are virtually inaccessible to human receptors without dredging or excavation equipment.

Alternative DS-3 (Removal and Off-Site Disposal) would provide the highest level of protection for human health because all contamination exceeding the PRG would be removed from the deep sediment remediation areas. However, the marginal benefit derived from Alternative DS-3 over Alternative DS-2 would be low, since deep sediments in their current state are virtually inaccessible to humans, with the exception of the dredging scenario that would be restricted or prohibited by institutional controls under Alternative DS-2 (Monitoring with Institutional Controls).

4.3.6.2 Compliance with ARARs

Alternative DS-1 (No Action) would not comply with action-specific or chemical-specific ARARs or risk-based PRGs identified as TBCs. Alternative DS-2 (Monitoring with Institutional Controls) would be protective and comply with chemical-specific ARARs by restricting work within the area of deep sediments, as long as the institutional controls are able to be adequately enforced. However, Alternative DS-2 (Monitoring with Institutional Controls) may not comply with action-specific or chemical-specific ARARs related to federal or state ambient water quality criteria for the protection of surface water since there would be no actions taken to abate sediment contamination which may degrade surface water quality. Surface water and sediment monitoring would be included with this alternative to verify compliance with these ARARs.

There are no location-specific ARARs that were identified for Alternative DS-1 (No Action) and Alternative DS-2 (Monitoring with Institutional Controls), since no on-site actions would be taken. Alternative DS-3 (Removal and Off-Site Disposal) would comply with all applicable ARARs and TBCs.

4.3.6.3 Long-Term Effectiveness and Permanence

Alternative DS-1 (No Action) does not provide any long-term effectiveness or permanence. Alternative DS-2 (Monitoring with Institutional Controls) would provide long-term effectiveness and permanence provided that institutional controls include enforceable, deeded, land-use restrictions or other appropriate institutional controls and requirements for regulatory oversight during any future dredging activities. This alternative would also require inspections to ensure that the institutional controls are effective at preventing human exposures to contaminated deep sediments.

The magnitude of residual risk would be highest for Alternative DS-1 (No Action) since no actions would be taken. The magnitude of residual risk for Alternative DS-2 (Monitoring with Institutional Controls) would be low since although no direct action is being taken to reduce contamination within the sediments, the likelihood that institutional controls would be an effective deterrent to human exposure to deep sediments is high.

Alternative DS-3 (Removal and Off-Site Disposal) provides the highest degree of long-term effectiveness and permanence because the sediments exceeding the arsenic PRG would be completely removed from the site and the resulting magnitude of residual risk would be low.

4.3.6.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative DS-1 (No Action), Alternative DS-2 (Monitoring with Institutional Controls), and Alternative DS-3 (Removal and Off-Site Disposal) do not provide any treatment of contaminants and do nothing to reduce the toxicity of the deeper sediment. Alternative DS-3 (Removal and Off-Site Disposal) may provide for limited off-site treatment if necessary to qualify for land disposal at a licensed landfill.

4.3.6.5 Short-Term Effectiveness

Because Alternative DS-1 (No Action) and Alternative DS-2 (Monitoring with Institutional Controls) would not require any onsite actions, there would be no short-term impacts to the community or to on-site workers.

Alternative DS-3 (Removal and Off-site Disposal) would have the most significant short-term impacts on the community and onsite workers. However, impacts to workers would be minimal since construction activities would be completed in accordance with appropriate health and safety procedures. Potential risks and hazards associated with fugitive dust emissions would be addressed with prescribed engineering controls. These impacts would mostly stem from inconveniences in traffic control during construction and/or excavation activities, as well as potential nuisance odors resulting from excavating large portions of a wetland.

No adverse environmental impacts would be anticipated from Alternative DS-1 (No Action) and Alternative DS-2 (Monitoring with Institutional Controls). Extensive and severe environmental impacts would be caused by Alternative DS-3 (Removal and Off-Site Disposal) during construction of haul roads, intrusions into the wetland areas to access the deep sediment locations, dredging or excavation of sediments, and restoration of the wetland areas. There would also be potential impacts due to creation of suspended solids during excavation. Although these impacts would be minimized by engineering controls and specialized construction methods during the remediation, periodic storm events and flooding could overwhelm the engineering controls and result in the uncontrolled release of contaminated sediments from work areas. Benthic communities and other wetland habitat features that are destroyed during sediment removal would eventually re-establish, but it may take a significantly long period of time to recover fully. These impacts would require mitigation both during and following remedial construction activities.

4.3.6.6 Implementability

Alternative DS-1 (No Action) and Alternative DS-2 (Monitoring with Institutional Controls) are the easiest to implement because there are no onsite remedial actions required. However, as discussed above, institutional controls under Alternative DS-2 (Monitoring with Institutional Controls) may be more difficult to complete due to potential delays that may be encountered with the inauguration of the actual institutional controls and deed attachment documents.

Alternative DS-3 (Removal and Off-Site Disposal) would be the most difficult to complete due to the complexities of access by dredging equipment to the interior portions of the wetlands in order to access the deep sediment areas as well as the significant volume of sediments requiring remediation. In addition, deep sediment locations are generally situated within the river channel and would likely require specialized removal methods. Specialized excavation or hydraulic dredging equipment would be required since the remediation areas extend hundreds of feet into the wetland areas (e.g. Well G&H wetland area). Also, Alternative DS-3 (Removal and Off-Site Disposal) requires additional tasks including dewatering of wetland sediments, water treatment, and restoration of a wetland area. The specialized equipment and expertise required to perform the work are available, but from limited sources.

RAOs for protection of human health would be achieved as soon as the institutional controls are implemented for Alternative DS-2 (Monitoring with Institutional Controls), and upon completion and removal of contaminated sediments under Alternative DS-3 (Removal and Off-Site Disposal).

4.3.6.7 Cost

The overall cost for each alternative is based upon the initial capital cost to construct the remedy and the annual operation and maintenance costs to maintain the integrity of the remedy over 30 years. Using a seven percent discount factor, the total remedy costs over a 30-year period are then calculated in a present-worth analysis.

Since no action is required for Alternative DS-1 (No Action), no costs would be incurred. Present-worth values for other alternatives are estimated as follows:

- Alternative DS-2 (Monitoring with Institutional Controls) $459,000
- Alternative DS-3 (Removal and Off-Site Disposal) $117,378,000

The cost for Alternative DS-3 (Removal and Off-Site Disposal) is volume dependent. This cost could vary significantly (plus or minus) depending on the actual limits of contamination exceeding the PRGs. The limits of contamination assumed for this FS are based upon widely spaced data, and additional studies should be performed prior to completing the final remedial design to more accurately delineate the extent of remediation required.

4.3.7 Comparative Analysis of Surface Water Alternatives

As part of the detailed analysis, this section presents an evaluation of the relative performance of each surface water alternative with regards to seven of the nine NCP evaluation criteria and is used in the selection of a remedial alternative by evaluating the advantages and disadvantages of each alternative in comparison to the NCP criteria.

Deep surface water in the HBHA Pond does not pose human health risks or hazards in excess of regulatory guidelines. Consequently, only environmental risks are specifically addressed by the selected remedial alternatives.

4.3.7.1 Overall Protection of Human Health and the Environment

Alternative SW-1 (No Action) offers no protection to the environment. If implemented in conjunction with other groundwater and sediment remedial alternatives, Alternative SW-2 (Monitoring) and Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would provide protection to the environment by monitoring and evaluating risks to the benthic community and evaluating potential reductions in contaminants due to natural attenuation processes or other remedial alternatives selected for groundwater and sediments.

Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would provide the highest level of environmental protection since an alternate habitat would be constructed to preserve the benthic community inventory within the watershed until the surface water is restored. RAOs would be achieved by Alternative SW-3 (Monitoring and Providing an Alternate Habitat).

4.3.7.2 Compliance with ARARs

Alternative SW-1 (No Action) would not comply with chemical-specific ARARs. If implemented in conjunction with other groundwater and sediment remedial alternatives, such as Alternative HBHA-4, then Alternative SW-2 (Monitoring) and Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would attain the action-specific and chemical-specific ARARs pertaining to federal or state ambient water quality criteria for site-related contaminants at the point of compliance. In the case of Alternative HBHA-4, the point of compliance would be immediately downstream of the cofferdams.

Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would comply with the surface water RAO, which is to provide an alternate habitat if the PRGs can not be achieved. Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would comply with all pertinent ARARs during the construction of the alternate habitat.

4.3.7.3 Long-Term Effectiveness and Permanence

The magnitude of residual risks would remain high for each alternative since contamination is not being removed from the surface water. Alternative SW-2 (Monitoring) and Alternative SW-3 (Monitoring and Providing an Alternate Habitat) do offer periodic monitoring and reviews to re-evaluate risks and monitor the degradation of contaminants through natural attenuation processes. In the long-term, once contaminated groundwater discharges are eliminated, natural attenuation processes, assumed for Alternative SW-2 (Monitoring) and Alternative SW-3 (Monitoring and Providing an Alternate Habitat), would either destroy residual organic contaminants (benzene) or reduce the toxicity and mobility of inorganic contaminants (arsenic) significantly lowering the magnitude of residual risk.

4.3.7.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

None of the surface water alternatives would provide any treatment of contaminants beyond that which would occur through natural attenuation processes present in deep surface water in the Pond.

4.3.7.5 Short-Term Effectiveness

Because Alternative SW-1 (No Action) would not require any action, there would be no short-term impacts to the community or to onsite workers. Since no onsite actions are required under Alternative SW-2 (Monitoring), other than periodic collection of environmental samples, there would be no impacts to the community. Potential impacts to workers under Alternative SW-2 (Monitoring) would be addressed by implementing appropriate health and safety and engineering controls.

Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would have the most short-term impacts on the community. Potential risks and hazards associated with fugitive dust emissions during construction of the compensatory wetland would be addressed with prescribed engineering controls. Impacts to workers would be minimal since construction activities would be completed in uncontaminated areas and would be conducted in accordance with appropriate health and safety procedures. Other non-health related impacts would result from inconveniences in traffic control during construction of the compensatory wetlands. Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would take the longest to implement from a construction schedule since it is the only alternative with onsite actions.

RAOs for protection of the environment would be achieved as soon as the compensatory wetland(s) is constructed and repopulated. The RAO for surface water under Alternative SW-2 (Monitoring) would not be achieved unless other groundwater and sediment alternatives are implemented in conjunction with Alternative SW-2 to address contaminated groundwater discharges and contaminated sediments.

4.3.7.6 Implementability

Alternative SW-1 (No Action) and Alternative SW-2 (Monitoring) would be the simplest alternatives to implement because there are no remedial actions required. Alternative SW-2 (Monitoring) would, however, require additional effort since periodic monitoring would be included.

Alternative SW-3 (Monitoring and Providing an Alternate Habitat), would be the most difficult tom implement due to the requirement to construct approximately five acres of compensatory wetlands in an urban setting. It may be difficult to locate large parcels of suitable available land within the watershed. It is reasonable to assume that the total acreage required will be met by several smaller parcels in different locations, which in the aggregate, comprise the 5-acre compensatory wetland requirement. The areas within the watershed are highly developed and it may be difficult and costly to acquire these properties.

Also, Alternative SW-3 (Monitoring and Providing an Alternate Habitat) would be more difficult to implement because construction of the compensatory wetlands would include tasks that require specialized design and construction skills. However, these skills are readily available from several sources.

4.3.7.7 Cost

The overall cost for each alternative is based upon the initial capital cost to construct the remedy and the annual operation and maintenance costs to maintain the integrity of the remedy over 30 years. Using a seven percent discount factor, the total remedy costs over a 30-year period are then calculated in a present-worth analysis.

Since no action is required for Alternative SW-1 (No Action), no costs would be incurred. Costs for other Alternative SW-2 (Monitoring) and Alternative SW-3 (Monitoring and Providing an Alternate Habitat), are estimated as follows:

- Alternative SW-2 (Monitoring) $ 3,226,000
- Alternative SW-3 (Monitoring and Providing an Alternate Habitat) $10,797,000

The cost for Alternative SW-3 (Monitoring and Providing an Alternate Habitat) is dependent upon the availability and actual purchase price of land required to construct the compensatory wetland(s). These costs could vary significantly (plus or minus) depending on the location and current use.

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REFERENCES

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